LEVEL II

2

SENSITIVITY OF SYSTEM READINESS TO RESOURCE ALLOCATION - A DEMONSTRATION

30 June 1980

Prepared For:

Office of the Chief of Naval Operations (OP 964C)
Department of the Navy
Washington, D.C. 20350

Prepared Under:

Contract No. N00014-79-C-0985

Advanced Technology, Incorporated
7923 Jones Branch Drive
McLean, Virginia 22102

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1. Enclosure (1) is forwarded for information and retention. It attempts to demonstrate the relationship between readiness of a particular system and the resources expended. Using two definitions of operational availibility for the AN/SPS-48 radar, a statistical correlation was attempted with twelve resource and other factors. The statistical results are inconclusive in establishing a definitive, quantifiable readiress-resources link. The report presents specific recommendations in areas with potential for establishing readiness-resource relationships.

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EXECUTIVE SUMMARY

SENSITIVITY OF SYSTEM READINESS TO RESOURCE ALLOCATION - A DEMONSTRATION

This study was undertaken to demonstrate the relationship between the readiness of a particular system and the resources expended in support of that system. It also attempts to test the relationship between readiness and other quantities, such as ship operating tempo, that had the potential for having a quantitative correlation with system readiness. The AN/SPS-48 Radar was chosen as the subject of the study over two other candidate systems because of its relative lack of complexity and because of the existence of an abundance of data in comparison to the other systems.

With the goal of demonstrating the readiness-resource correlation, two rather than one readiness definition, ~~(R_1 and R_2)~~ were used to increase the potential for success.

$$R_1 = \frac{\text{radar operating time}}{\text{radar operating time} + \text{radar downtime}}$$

$$R_2 = \frac{\text{calendar time} - \text{radar downtime}}{\text{calendar time}}$$

Using the data base assembled, scatter diagrams of the observed system-level readiness versus each resource (or other) variable were constructed. From these scatter diagrams rigorous trend and correlation analyses were undertaken. Statistical analysis was undertaken for ~~the following~~ variable pairs:

- Readiness (R_1 and R_2) versus Organizational Man-hours
- Readiness (R_1 and R_2) versus Organizational Parts Expenditures
- Readiness (R_1 and R_2) versus Depot Man-hours
- Readiness (R_1 and R_2) versus Depot Parts Expenditures
- Readiness (R_1 and R_2) versus Maintenance Personnel Availability
- Readiness (R_1 and R_2) versus Ship Operating Intensity (using estimated radar operating time)
- Readiness (R_1 and R_2) versus Ship Operating Intensity (using actual radar operating time).
- Readiness (R_1 and R_2) versus Maintenance Downtime
- Readiness (R_1 and R_2) versus Supply Downtime
- Readiness (R_1 and R_2) versus Calendar Time
- Readiness (R_1 and R_2) versus Actual Radar Operating Time
- Readiness (R_1 and R_2) versus Estimated Radar Operating Time

The conclusions are presented in summary form in the following table:

SUMMARY OF TREND ANALYSIS

VARIABLE SET	OBSERVED TREND
1. R_1/Organizational Man-hours	No Trend
2. R_2/Organization Man-hours	No Trend
3. R_1/Organizational Parts Expenditure	No Trend
4. R_2/Organizational Parts Expenditure	No Trend
5. R_1/Depot Parts	Readiness tends to decrease in the two reporting periods immediately following a depot availability
6. R_2/Depot Parts	
7. R_1/Depot Man-hours	
8. R_2/Depot Man-hours	
9. R_1/Maintenance Personnel Availability	Readiness tends to increase slightly with increases in maintenance personnel availability
10. R_2/Maintenance Personnel Availability	
11. R_1/Calendar Time	No Trend
12. R_2/Calendar Time	No Trend
13. R_1/Ship Operating Intensity	No Trend
14. R_2/Ship Operating Intensity	No Trend
15. R_1/Time Awaiting Parts	No trend when all data points are considered--inverse correlation (Low) when spurious data points are excluded
16. R_2/Time Awaiting Parts	
17. R_1/Supply Downtime	High inverse correlation in 30% of radar serials
18. R_2/Supply Downtime	High inverse correlation in 75% of radar serials
19. R_1/Maintenance Downtime	No trend when all data points are considered--slight inverse correlation when spurious data points are excluded
20. R_2/Maintenance Downtime	High inverse correlation in 30% of the radar serials

20.	R/Maintenance Downtime	High inverse correlation in 30% of the radar serials
21.	R_1/Radar Operating Time	No Trend
22.	R_2/Radar Operating Time	No Trend

The statistical results as noted, are inconclusive in establishing a definitive, quantifiable readiness-resources link. Further pursuit of attempts to quantify the resources-readiness correlation without some significant revisions to methodologies employed is not recommended. Sections of the report present specific recommendations in areas with potential for establishing quantitative readiness-resource correlations.

Several revisions/modifications to data sources are recommended in section 7.0 of the report. These recommendations are primarily focused toward changes that would benefit fleet technicians and operational planners in making quantitative readiness determination without generating additional reporting requirements on fleet personnel. Due to the lack of available data in preparing the study, several logical resource-readiness pairs could not be determined. These are outlined in Section 7.0.

1.0 DEMONSTRATIONS OF READINESS VERSUS RESOURCES - AN OVERVIEW

Congressional pressure on the Navy to respond to questions concerning the readiness of our forces and the cost of maintaining this readiness has been a motivation for performing numerous resources-to-readiness studies. The Center for Naval Analysis recently published a bibliography of resources-to-readiness studies prepared during the past decade. The bibliography documents over one hundred attempts to link readiness (defined in various ways) to resources expended. The studies approach the problem using a variety of analytical methods ranging from statistical analysis to simulation modeling. As documented, an enormous volume of data has been analyzed and processed in various ways. Yet, even with these large efforts, the Navy has been unable to satisfactorily establish a standard methodology to tie readiness-to-resource expenditures and thereby respond to outside pressures. There are numerous problems that have hampered progress in establishing the readiness-to-resources link that intuitively should exist. The scope of the study was limited by selecting a single shipboard system which has received extensive attention and corresponding documentation over the past 10 years. Several systems were initially considered to possess these characteristics, however, the AN/SPS-48 Radar was chosen for the study. The rationale for choosing it over other systems is presented in Section 2.0.

1.1 Study Objectives

This study was undertaken with the benefit of the experiences of the numerous studies that preceded it. Thus, the study's approach and objectives are, in some respects, more concentrated than previous efforts that, in some cases, examined entire ship classes and their vast scope of support resources. In accordance with the statement of work, the study's title, "Sensitivity of System Readiness to Resource Allocation - A Demonstration," suggests the narrow focus of the effort. Using a single system, the study attempted to determine whether any measurable statistical relationship exists between resource allocation and system readiness. A secondary objective of the study was to determine whether other factors could be statistically linked to readiness. Factors such as operational intensity, time awaiting spare parts, and others were examined in pursuit of the secondary objective.

The study also provides an analysis that was not originally included in the scope of the project. An economic analysis has been attempted to relate the impact of resources on the equipment readiness. This analysis was performed on the basis of marginal rates of return on resource investment.

1.2 Report Organization

This final report on the study is organized into six additional major sections plus appendices.

Section 2.0, General Approach, covers the system selection process. It discusses the final three candidate systems that were considered for the analysis and the reasons for choosing the AN/SPS-48 Radar over the other systems. It discusses the statistical readiness measures that were used in the analysis and illustrates the differences between the two. The approach used to define resource measures that were tracked is also presented in Section 2.0.

In Section 3.0 the Analytical Approach used in the study is delineated. It defines schematically the processes used to gather, assemble, and analyze the resource-readiness data base.

The Data Source Analysis, Section 4.0, describes the data sources used and discusses their merits and shortcomings. The data sources that were felt to be integral to the study, but were, for a variety of reasons, unavailable, are also discussed in Section 4.0.

Section 5.0 is the Statistical Analysis. It is divided into two major areas. The first analyzes the relationship between radar readiness and the variety of resources that are applied to the radar. The second area is an analysis of readiness in relation to other factors, including ship operational intensity and time spent awaiting spare parts for the radar.

Section 6.0 is an Economic Analysis of readiness versus resources. This section attempts to relate the impact on readiness of resources applied to the radar.

Conclusions and Recommendations of the study are found in Section 7.0. This section covers the findings generated in the analytical portions (Sections 4.0, 5.0, 6.0) of the report.

2.0 GENERAL APPROACH

Section 2.0 discusses the process used in choosing the most promising shipboard system to be used in the readiness-resource analysis. It also details the criteria considered for selection of the ships on which the AN/SPS-48 Radar is installed. Readiness measures used in the analysis and resources that were examined are discussed. A description of other quantities (operating time, etc.) is also presented.

2.1 System Selection

Numerous systems were considered in the selection process and were ultimately narrowed to the three systems, each discussed in the sections to follow. The following list of questions was used as the criteria for choosing the best study subject:

- Was the system clearly definable? That is, can clear boundaries be drawn around the system isolating it from other ship systems?
- Did existing system configuration and documentation lend itself to a study of this nature?
- Was the system population large enough for quantitative analysis?
- Had the system been in existence long enough to enable the development of a historical data base of sufficient size for the study?
- Could the system readiness be tracked based on data availability?
- Could system resource expenditures in support of the system be tracked based on data availability?

The three systems that were the final candidates for the study were the Terrier Missile System, the AN/SQS-26 CX Sonar, and the AN/SPS-48 Radar. These three systems substantially satisfied the criteria presented above. In order to choose one of the three, a careful examination of the systems was made. The system determination matrix (Table 2-1) outlines the systems and illustrates the various factors considered in system selection. A discussion of each system follows the matrix.

2.1.1 The Terrier Missile System

Although the Terrier Missile System (TMS) was a good candidate for the study, several problems would have resulted The major obstacle was the relative complexity of the system in terms of the large number of major subsystems and components which make up the TMS, and in terms of the somewhat undefined boundaries that exist between Terrier and other shipboard systems. When attempting to determine the readiness of the entire system, the effect of performance degradation of any of these subsystems/components must be related to the system as a whole. This makes the quantitative determination of the degree of system degradation very difficult.

SYSTEM DETERMINATION MATRIX TABLE 2-1

	TERRIER MISSILE SYSTEM	AN/SQS-26 CX SONAR	AN/SPS-48 RADAR
I. SYSTEM DEFINITION			
A. Configuration of Major Subsystems and Components	1. Weapons Direction System (MK 11 or 14)	1. Transmitter	1. Antenna
	2. Fire Control System	2. Receiver	2. Transmitter
	a. AN/SPS-55 Radar Antenna Director Pulse Transmitter 2 Receivers High-Voltage Components Low-Voltage Components Tracking Console Cooling System	3. Power Supply 4. Display 5. Transducer	3. Receiver 4. Computer 5. Console
	b. MK 152 Computer Computer Signal Data Converter Input-Output Console	6. Fire Control Computer	
	3. MK 10 Launcher Magazine Ready Service Area Launcher		
	4. Missile		

TABLE 2-1 (2)

	TERRIER MISSILE SYSTEM	AN/SQS-26 CX SONAR	AN/SPS-48 RADAR
B. Modifications	9 Modifications (4 Mods in use)	Numerous Field Changes	3 Modifications
C. Ability to Define System	• Not on Navy-selected equipment list • Centralized Project Office • System Data not saved beyond 6 months, thus requiring numerous sources for data collection	• Not on Navy-selected equipment list • Project Engineer has cognizance over several other sonars • No longer centralized reporting system	• Navy-selected equipment • PARM with cognizance over one system • PARM has reliability data available • Centralized computer data base for system
II. ABILITY TO DEFINE RESOURCES EXPENDED			
A. Maintenance Sources	Organizational IMA SIMA Tenders Depot MOTU NAVSEACENLANT NSWSES Shipyards	Organizational IMA SIMA Tenders Depot Shipyards	Organizational IMA NAVSECNORDIV MOTU Depot Shipyards

TABLE 2-1 (3)

	TERRIER MISSILE SYSTEM	AN/SQS-26 CX SONAR	AN/SPS-48 RADAR
A. Maintenance Sources (Cont.)	Vendors General Dynamics Sperry UNIVAC Ocean Technology	Vendor General Electric	Vendor ITT/Gilfillan
B. Reports Required for Study	NAMSO NAVSEACENLANT TERRIER Monthly Report Missile Readiness Report CONAR CASREPS FORSTATS Deficiency Corrective Action Program (DCAP) Shipyard Departure Report Missile Firing Reports MOTU Time Expenditure Report	NAMSO CASREPS CONAR FORSTATS Shipyard Departure Report IMA Expenditure Report MOTU Time Expenditure Report	DSMOL NAMSO CASREPS CONAR FORSTATS Shipyard Departure Report MOTU Time Expenditure Report

TABLE 2-1 (4)

	TERRIER MISSILE SYSTEM	AN/SQS-26 CX SONAR	AN/SPS-48 RADAR
II. ABILITY TO DEFINE RESOURCE ALLOCATIONS			
A. Material Resource Allocation	Numerous EICs, thus necessitating multiple supply reports	1 EIC	3 EICs ● NAVSECNORDIV keeps supply data by EIC --available 1976 --available on tape to 1970 (w/funding)
B. Personnel Resources	3 NECs for each Modification	1 NEC 4 Secondary NECs	1 NEC for each MOD

Another problem encountered with the TMS was the nine different modifications of the system, four of which are presently in use in the fleet. Because of the modifications, which evolved primarily as a result of changes to the system to improve its reliability, analytical problems exist in attempting to relate all of the installed modifications to some baseline.

In determining material resource allocation, the numerous EICs associated with the TMS require that an enormous volume of supply data (when compared to other systems) be analyzed in the study. Finally, although there is a centralized TMS Project Office (NAVSEA 62Z1) and a wealth of hard data collected, the office reported that a good portion of the material is not saved beyond 6 months. Thus, reassembly of historical data using a variety of data sources would have been the result.

2.1.2 AN/SQS-26 CX Sonar

Another system considered as a good subject for the study was the AN/SQS-26 CX Sonar. Although more attractive than the TMS in terms of having a less complex equipment configuration breakdown, the AN/SQS-26 CX Sonar, when examined in detail, also proved to be less desirable than AN/SPS-48 Radar.

When it was o ginally introduced into the fleet, the AN/SQS-26 CX Sonar was the subject of intensive performance and maintenance monitoring with a centralized reporting system and a dedicated project office. Currently, the AN/SQS-26 project engineer, NAVSEA 63, has cognizance over several other sonars. In addition, the AN/SQS-26 project office no longer exists, nor does the monitoring system. Consequently, this makes the resources-readiness data base capture as difficult as that for the TMS.

2.1.3 AN/SPS-48 Radar

The third system analyzed as a candidate for study was the AN/SPS-48 Radar. The AN/SPS-48 Radar was more attractive than the TMS in terms of configuration (i.e., fewer subsystems/components) and, by the same criteria, was approximately the same as the SQS-26 Sonar. The primary reason for selecting the AN/SPS-48 over the other two systems considered was the existence of a PARM in NAVSEA (62X31) with cognizance over just the AN/SPS-48. This NAVSEA code maintains a large amount of the reliability data needed for the study, thus somewhat alleviating the data gathering process.

The existence of a vendor-maintained document series, the AN/SPS-48 Shipboard Reliability Support Program Quarterly Reports, was a large factor in choosing the radar as the system to be studied. Information received from the vendor stated that the report would be an excellent source for readiness and resources data required for the study, thus lessoning the importance of 3-M data, CASREP data, and other data sources (a desirable attribute in light of the failures of previous studies which used such data).

After the AN/SPS-48 was chosen, some problems with the vendor report emerged and, finally, only portions of the report were in fact usable. (See Section 4.1.8 for a thorough discussion.)

In summary, the radar was chosen for the following reasons:

(a) The system configuration was less complex and more easily defined than the Terrier Missile System.

(b) There are fewer modifications to the radar than to the other two systems.

(c) A centralized report existed containing a good portion of the data needed.

(d) A dedicated NAVSEA program officer exists to support the radar on a full time basis.

2.2 Ship Selection

This section details the selection process used for determining which ships carrying the AN/SPS-48 Radar would be used for the study. Table 2-2 lists the ships included in the study, the serial number of the AN/SPS-48 installed on each unit, and the time frame for which data were available on each ship's installation.

The AN/SPS-48 Radar is the primary 3-D, air-search radar aboard most DDG and CG class vessels. It is also installed aboard LCC-19, LCC-20, and several aircraft carriers, and at a few training commands. Due to the specialized role and mission areas associated with the LCC class, these units were excluded from the study. The same decision was made with respect to the carriers, due to the fact that several other carrier-based systems can be used to perform the 3-D, air-search function aboard those ships. Land-based test sites were also excluded due to their special function.

All DDG and CG classes with the AN/SPS-48 were chosen for inclusion in the study because of the large data base these ships represent, and because of the common missions of the ships.

2.3 Readiness Measures Used

The nature of the study--a demonstration--necessitated the testing of two rather than one, empirically derived, material-readiness measures. These measures, R_1 and R_2, are presented on page 2-8.

Table 2-2
DATA AVAILABILITY MATRIX

UNIT	RADAR SERIAL	DATA AVAILABILITY
USS GRIDLEY (CG-21)	C 12	1 January 1972 - 30 June 1979
USS ENGLAND (CG-22)	C 4	1 April 1972 - 30 June 1979
USS HALSEY (CG-23)	D 2	23 December 1972 - 30 June 1972
USS REEVES (CG-24)	C 13	1 January 1972 - 30 June 1989
USS BAINBRIDGE (CGN-25)	E 5	18 August 1976 - 30 June 1979
USS JOUETT (CG-29)	A 9	1 January 1972 - 30 June 1979
USS STERETT (CG-31)	A 11	1 January 1972 - 30 June 1979
USS HORNE (CG-30)	A 7	1 January 1972 - 30 June 1979
USS WM. H. STANDLEY (CG-32)	A 4	1 January 1972 - 30 June 1979
USS FOX (CG-33)	A 5	1 April 1972 - 30 June 1979
USS PARSONS (DDG-33)	B 2	27 September 1971 - 30 June 1979
USS TRUXTON (CGN-35)	A 3	1 January 1972 - 30 June 1979
USS TEXAS (CGN-39)	E 2	15 October 1976 - 30 June 1979
USS CALIFORNIA (CGN-36)	C 17	29 March 1975 - 30 June 1979
USS ALBANY (CG-10)	B 7	1 April 1971 - 30 June 1979
USS YARNELL (CG-17)	D 7	1 April 1972 - 30 June 1979
USS J. DANIELS (CG-27)	C 9	1 January 1972 - 30 June 1979
USS DALE (CG-19)	A 6	1 January 1972 - 30 June 1979
USS WORDEN (CG-18)	C 15	1 January 1972 - 30 June 1979
USS LEAHY (CG-16)	B 6	1 January 1972 - 30 June 1979
USS WAINWRIGHT (CG-28)	A 1	1 April 1972 - 30 June 1979
USS COONTZ (DDG-40)	C 14	1 April 1972 - 30 June 1979
USS KING (DDG-41)	C 1	31 March 1977 - 30 June 1979
USS MAHAN (DDG-42)	C 6	29 March 1975 - 30 June 1979
USS LUCE (DDG-38)	C 18	1 January 1972 - 30 June 1979
USS VIRGINIA (CGN-38)	E 3	15 October 1976 - 30 June 1979

Table 2-2(2)

UNIT	RADAR SERIAL	DATA AVAILABILITY
USS DECATUR (DDG-31)	A 13	1 July 1971 - 30 June 1979
USS JOHN PAUL JONES (DDG-32)	B 1	1 January 1971 - 30 June 1979
USS SOMERS (DDG-34)	B 3	1 January 1972 - 30 June 1979
USS MITSCHER (DDG-35)	B 4	1 January 1971 - 30 June 1979
USS FARRAGUT (DDG-37)	C 3	1 January 1971 - 30 June 1979
USS PRATT (DDG-44)	D 5	3 December 1973 - 30 June 1979
USS MACDONOUGH (DDG-39)	D 6	29 April 1974 - 30 June 1979
USS DAHLGREN (DDG-43)	D 4	2 April 1973 - 30 June 1979
USS DEWEY (DDG-45)	C 8	1 January 1972 - 30 June 1979
USS PREBLE (DDG-46)	C 5	1 April 1972 - 30 June 1979

2.3.1 R_1

$$R_1 = \frac{\text{operating time}}{\text{operating time + downtime}}$$

R_1 is the mathematical equivalent of the commonly accepted definition of availability (A), as shown below:

$$A = \frac{\text{MTBF}}{\text{MTBF + MTTR}}$$

$$\text{MTBF = mean time between failures} = \frac{\text{operating time}}{\text{number of failures}}$$

$$\text{MTTR = mean time to repair} = \frac{\text{downtime}}{\text{number of failures}}$$

N = number of failures

$$R_1 = \frac{\frac{\text{operating time}}{N}}{\frac{\text{operating time}}{N} + \frac{\text{downtime}}{N}} = \frac{\text{operating time}}{\text{operating time + downtime}}$$

operating time = operational hours of the AN/SPS-48 receiver and power supply

R_1 (in lieu of A) was adopted to more conveniently use available data. Operating time in the equation was taken from the AN/SPS-48 Shipboard Reliability Support Program Quarterly Reports. Downtime was obtained from radar Casualty Reports (CASREPs) for the various units. (To have calculated a MTBF and MTTR would have required an additional step in the process, and, as illustrated, would have yielded the same quotient, R_1.

2.3.2 R_2

$$R2 = \frac{\text{calendar time - downtime}}{\text{calendar time}}$$

Calendar time = total number of hours in a reporting period correspond to the Quarterly Reports. Downtime = same as in R_1.

The implications associated with these two formulas are significantly different. R1 looks at the time when the radar is actually radiating, and at the time when the system is known to be down. The radar is assumed to be ready only during the time when it is actually satisfactorily operating. R2 is more optimistic than R1 in that the radar is assumed to be ready any time the radar is not known to be down (i.e., when inport is not operating and is assumed to be ready, based on previous test or use).

When calculating readiness, some striking differences in the results the formulas yield are apparent. The following examples illustrate their differences.

Examples: A ship returns to port on January 1 with a radar that has failed. The radar is not repaired throughout the quarter.

$$R_1 = \frac{0}{0 + 90 \text{ days}} = 0$$

Another ship returns to port on the same day with a radar that is in perfect condition. The radar is not operated the rest of the quarter.

$$R_1 = \frac{0}{0 + 0} = 0^1 \qquad R_2 = \frac{90}{90 + 0} = 1.0$$

As illustrated, two radars with opposite conditions have the same result using the R_1 readiness measure. When we compare R_1 and R_2 when the radar is operational, the results are quite different.

The calculations presented are not intended to prejudice the use of either readiness measure. Rather, they are presented to illustrate the distinction between the two approaches and the potential for extreme differences in the results.

2.4 Resource Measures Used

The traceable resources applied to sustain the AN/SPS-48 Radar were assembled in the data collection phase of the study. Some significant difficulties exist in discriminating between the various layers or degrees of support applied to the system. Definitive parameters had to be established in order to realistically assess resource expenditures.

The difficulties of this discrimination process can be illustrated by portraying the support and resources actually applied to the radar. Figure 2-1 illustrates in a simplified fashion the various chains of logistic support that must function in order to properly support the system. The figure illustrates two of the logistic chains. One illustrates the development of a shipboard radar technician, the other shows the development of a spare part to be installed in the radar. (Other required logistics support chains are labeled but have not been completed.)

The question raised by the illustration is clearly that of boundary and limit establishment. How far away from the center do we need to go in order to determine precisely how much money, materials, and time are actually spent in supporting the radar? How many of these radar costs can be realistically traced to determine the proportion of resources at various levels that have an impact on system readiness?

It is clearly impossible to trace the resources applied to the radar back to raw materials or to the seaman recruit. In the case of spare parts it is easier to establish a boundary than it is for the personnel resources since it is assumed that the cost of the end item includes all the elements

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[1] It is understood that the actual quotient to this equation is only defined in its limits.

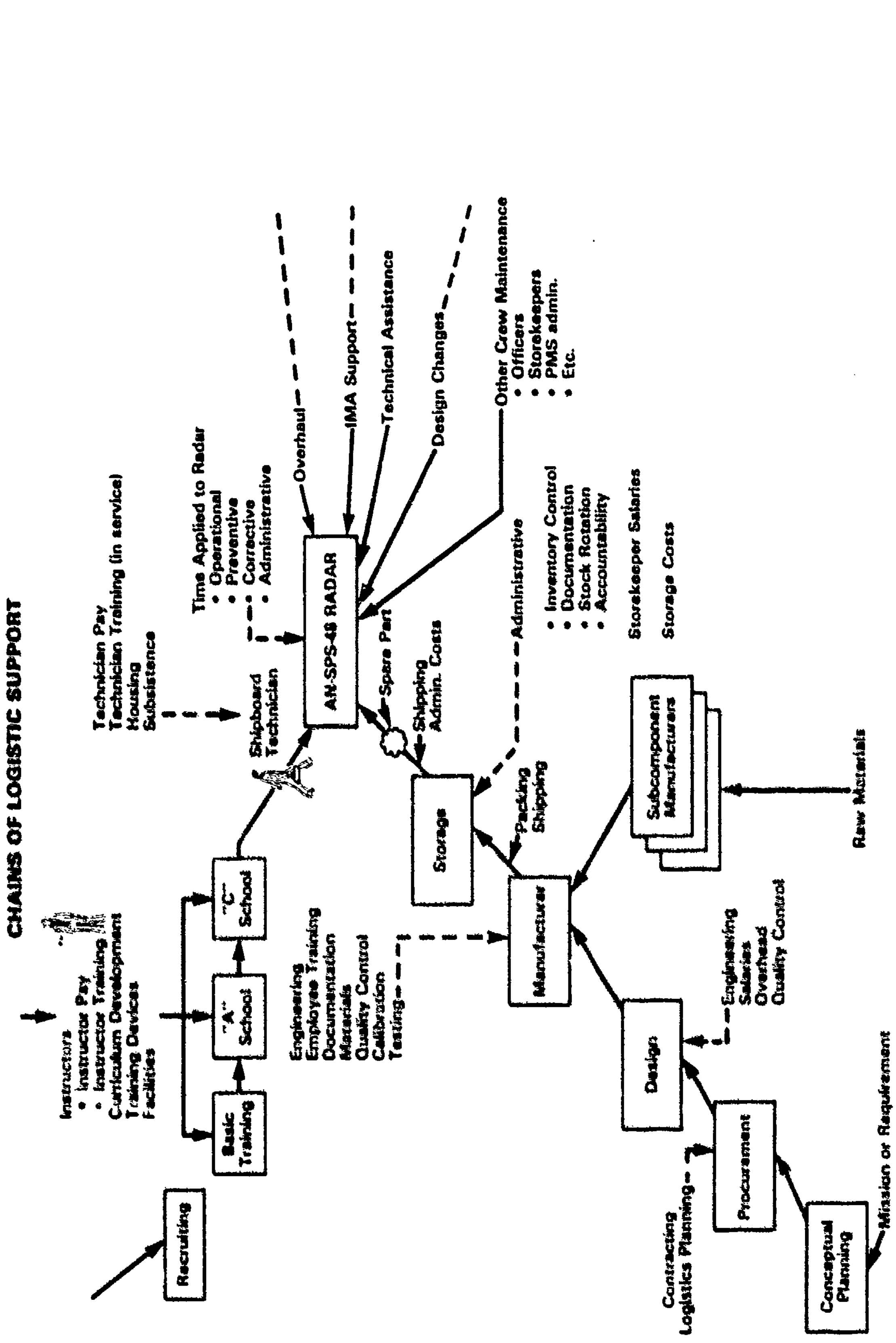
CHAINS OF LOGISTIC SUPPORT
Instructors
• Instructor Pay
• Instructor Training
Curriculum Development
Training Devices
Facilities
Recruiting
Basic Training
"A" School
"C" School
Shipboard Technician
Technician Pay
Technician Training (in service)
Housing
Subsistence
Time Applied to Radar
• Operational
• Preventive
• Corrective
• Administrative
AN-SPS-48 RADAR
Overhaul
IMA Support
Technical Assistance
Design Changes
Other Crew Maintenance
• Officers
• Storekeepers
• PMS admin.
• Etc.
Spare Part
Shipping Admin. Costs
Administrative
• Inventory Control
• Documentation
• Stock Rotation
• Accountability
Storekeeper Salaries
Storage Costs
Storage
Packing Shipping
Engineering
Employee Training
Documentation
Materials
Quality Control
Calibration
Testing
Manufacturer
Subcomponent Manufacturers
Raw Materials
Engineering
Salaries
Overhead
Quality Control
Design
Contracting
Logistics Planning
Procurement
Conceptual Planning
Mission or Requirement

Figure 2-1

of the chain which preceded it. In the case of the personnel chain, man-hours applied are the trackable quantity; however, these man-hours do not include the huge investment that is associated with training and development. The numerous activities that in some way contribute to radar performance significantly complicate the problem in that each support entity provides a different level of support, each with a different cost in terms of labor and materials. Additionally, the fact that comprehensive records on support activities performed and expenditures made are often unavailable, especially in the case of records over 3 years old. These difficulties in assessing what resources are applied to the radar and, of those, which resources are traceable via existing documentation, require that great care be exercised in determining which quantities should be and can be tracked. A discussion of resources that were determined to offer the best potential for demonstrating the relationship between readiness and resources follows.

2.4.1 Resources Tracked

This section presents those resources chosen for inclusion in the study. The choices are made primarily due to the availability of data rather than to desired resources. (See Sections 4.2 and 4.3 for resource data sources that were unavailable or could not be used.)

a. Corrective Maintenance Man-hours - It logically follows that if corrective maintenance man-hours are applied by qualified technicians when the radar is in a down state, that the radar should experience an increased level of readiness following that expenditure. (This assumes that the system is not in a "wear out state.") There are many variables to be considered in tracking corrective maintenance, including technician qualifications, technical documentation adequacy, training, working conditions, availability of support and test equipment, and others. These quantities, however, are substantially untrackable (based on available data), and several of them are subjectively measured. It has been assumed, therefore, that these remain constant for the large sampling of ships over the 10-year period considered in the study. Corrective maintenance man-hour tracking for the AN/SPS-48 is less complex than for other comparable systems (see Section 2.1) because fewer organizations are designated to provide support, thus limiting the sources to be examined. (For example, no Intermediate Maintenance Activities (IMAs) provide assistance on this radar except MOTU.) Only corrective maintenance man-hours were considered in this category. No expenditure for installations of modifications or alterations have been included. In shipyard departure reports where man-shifts or man-days were the units given, they were multiplied by 8 to produce man-hours, in order to be consistent with other manpower data.

b. Parts Costs - Parts cost expenditures are available over the 10-year period via Navy Maintenance Support Office (NAMSO) reports. In order to adjust the parts expenditure costs to compensate for inflation over the 10-year period, the Bureau of Labor Statistics Material Index for Steel Vessel Construction was used to convert each year's expenditures to 1967 dollars. When analyzed, periods following large parts expenditures should logically experience increased readiness. Examination of other trends such as steady rates of expenditure yielding steady levels of readiness have also been examined.

2.5 Other (Non-Resource) Quantities Considered

The following other factors have been considered in the analysis:

a. Time - Readiness was compared with the passing of time in an attempt to discern any trends.

b. Operational Intensity - Although not a resource, operational intensity was also included in the study to determine its relationship with readiness. Operational intensity took the form of the ratio of hours at sea versus hours in port per reporting period.

c. Time Spent Awaiting Parts - Time spent awaiting parts was also tracked using NAMSO reports. If it can be shown that time spent awaiting parts detracts from system readiness, it naturally follows that spare parts stocking and procurement methods should be examined to see if increased expenditures would yield increased readiness. The root of a problem in the logistics chain could lie in any of hundreds of areas ranging from unavailable raw materials to inadequate shipping procedures. If correlation exists, additional examination will be required.

d. Readiness Definition Components - Analyses of readiness definition component parts including maintenance downtime and supply downtime. (Subsets of total downtime and radar operational time versus readiness was performed to test the sensitivity of the readiness measures to these quantities.)

e. Personnel Availability - Ideally, the desired statistics in this area would be a historical record of billets allowed per fleet unit versus technicians actually filling those billets. This type of record would be useful to compare the how available manpower was used in the fleet and the effect of manpower deficiencies on readiness. Unfortunately, such data are not available without a sizable data retrieval effort consisting of individual service record reviews. Some data consisting of total Navy billets allowed by Navy Enlisted Classification (NEC) were available, however. In analyzing this information, it is necessary to assume that distribution of these bodies was equitable and that manpower was actually applied to ships with the AN/SPS-48.

3.0 ANALYTICAL APPROACH

The primary objective of this study is to develop a statistically rigorous methodology which demonstrates the sensitivity (or lack thereof) of system readiness to varying levels of resource support. As mentioned previously, this is not the first attempt at quantifying the intuitively appealing hypothesis that the level of resources available to support a system affects the operational readiness of that system. In light of the limited success achieved by some one hundred previous analytical studies, it was decided to construct a flexible "bottom-up" analytical approach consisting of a series of statistical evaluations. In this case, the bottom-up descriptor applies to both (1) the order of investigation (that is, examine first the data at the individual ship level and build by aggregating the input data in successively larger groups such as configuration groupings and fleet groupings); and (2) the building of an analytical approach based on the results of a series of successively more focused statistical evaluations. By utilizing intermediate analyses as decision points in determining the course of succeeding analyses, maximum technical flexibility can be retained, while minimizing the potential failure of the study due to strict adherence to an individual technique selected prior to the initiation of the analytical phase of the study. This approach allows the researcher to adjust the analytical approach to the problem on the basis of the total available information at each intermediate point of analysis.

In order to prevent this progressive, analytical approach from becoming a random statistical analysis, it is necessary to establish a list of statistical objectives of the study, and pursue only those statistical evaluations related to these objectives. In order for the methodology developed as a result of this study to be useful to those charged with making budgetary decisions, it must provide the following:

- A physical interpretation of observed trends and variable relationships (associations) among readiness measures and resource levels
- A quantitative measure of the "strength" of the relationship between associated variables
- A mathematical equation relating the variation in system readiness resulting from various levels of resource support
- A procedure for statistically validating the credibility of the readiness-estimating equation discussed in the preceding bullet.

In addition, the analytical approach must be logical, comprehensive, and reproducible.

Figure 3-1 schematically outlines the analytical approach undertaken for this study. The first five levels of activity relate the development of a resource/readiness data base to be utilized by all succeeding statistical analyses. The first statistical analysis of the data occurs at Level 6 where scatter diagrams are prepared for each bivariate (variable pair) analysis. The variables of interest at this phase of analysis are:

- Readness - actually two independent measures of system readiness referred to as R_1 and R_2
- Operating Time - the time the radar is actually operating
- Operating Intensity - the percentage of days at sea in comparison to the total days in a period
- Maintenance Downtime - the time that the radar is down that is spent troubleshooting and making repairs
- Supply Downtime - the time a system is down awaiting the arrival of repair parts
- Time Awaiting Parts - the time spent awaiting all spare parts ordered for the radar
- Corrective Maintenance Man-hours - hours spent performing organizational-level corrective maintenance
- Corrective Maintenance Parts Expenditures - the cost of spare parts ordered to repair the radar.

Based on a visual inspection of the scatter diagrams, subjective judgments are made on the observable trends and potential variable correlations. Each radar set is first analyzed individually for trends or causal relationships between variables, after which all like scatter diagrams--that is, scatter diagrams relating the same two variables but for different radar sets--are grouped to determine if common trends are observable among the radars or within configuration subsets.

After completing a visual inspection and physical interpretation of all of the scatter diagrams is completed, the Pearson product moment correlation coefficient is calculated for each variable pair exhibiting a possibility of statistical correlation. (As will be explained more fully in the Analysis section, Pearson product moment correlation coefficients were actually calculated for all variable pairs because of the paucity of trends/variable associations visually observable from the scatter diagrams.) The Pearson product correlation coefficient, or correlation coefficient as it will be referred to hereafter, is a maximum likelihood estimator of the strength of variable associations. The correlation coefficient can range in value from -1 to 1. The sign of the coefficient indicates the nature in which the two variables are related, that is, a positive sign indicates that high values of one variable are associated with high values of the other variable, whereas a negative sign indicates that high values of one variable are associated with low values of those other variables. The magnitude of the correlation coefficient actually measures the strength of the association. If the correlation coefficient is equal to 1 or -1, the two variables are said to be perfectly correlated; that is, the variables are exactly relatable by a straight line. When the correlation coefficient is equal to 0, the variables are uncorrelated, thus implying no linear association between the variables.

Variable pairs will be selected for regression analysis based on the strength of association between each of the variable pairs. High coefficients suggest useful regression equations. In regression analysis the variation of one variable, called the dependent variable, is mathematically determined as a function of the other variable known as the independent variable. Based on the results of the scatter diagram and the correlation coefficient analysis, a determination will be made for each variable pair as to the most appropriate form of regression, (i.e., linear, quadratic, and polynomial). In any case, the least-squared curve fitting critieria will be used as the "best fit" criteria.

In order to interpret the appropriateness of the regression equation, the statistical significance and the standard error of the regression coefficients and constants will be calculated. These statistics are to be used to test the hypothesis that the regression equation is a better estimator (hence, statistically significant) of the dependent variable than the arithmetic mean of all dependent variables in that observation--that is, the regression equation is useful in predicting the value of the independent variable.

When all of the scatter diagrams, correlation coefficients, regression equations, and hypothesis tests are concluded, the results will be reviewed to determine if common or disparate trends/associations are observable among radar sets, or within configuration groupings. Explanations underlying each of these trends/associations will be sought, and attempts will be made to focus on either an individual or a composite relationship which demonstrates a positive interaction between support resources and observed readiness. If such a relationship exists, then a positive linkage between resources and readiness will have been established. In addition, a methodology will have been validated which is statistically sound, comprehensible, and applicable to other systems.

ANALYTICAL APPROACH

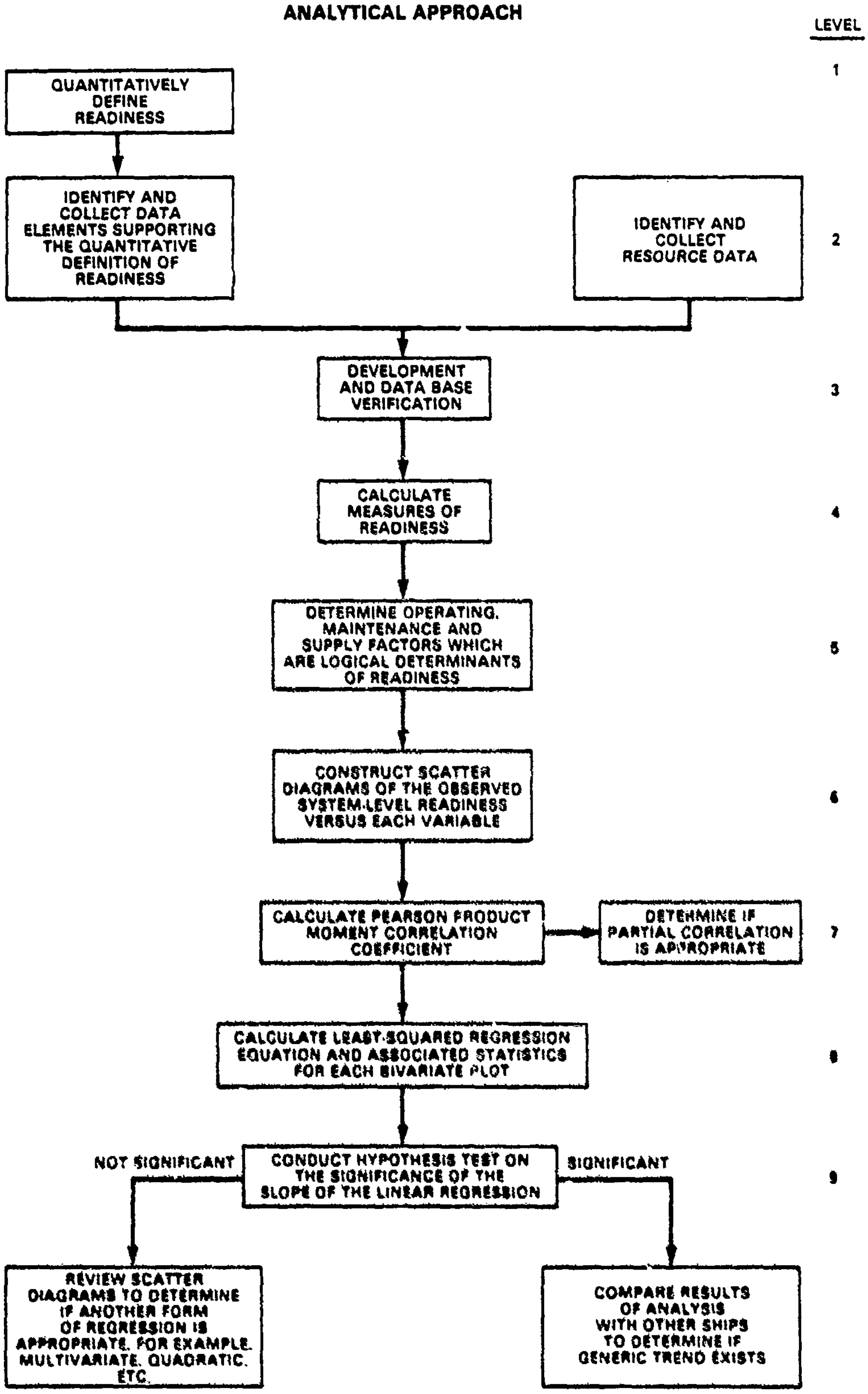

Figure 3-1

4.0 DATA SOURCE ANALYSIS

The purpose of this section is to analyze the data sources that were used in the study. The section points to the various sources' strengths and weaknesses as well as to their usefulness in performing the analysis. This section also considers data elements and data sources that were pursued in the course of the study, but were not available for reasons presented.

The matrix provided below (Table 4-1), displays the various reports and their originators. The data elements obtained from each are presented in the table. A discussion of these reports follows the table.

4.1 Individual Report Analysis

This section provides detailed analyses of each of the reports cited in Table 4-1. The reports are examined in terms of their contribution to the study, their availability, and their strengths and limitations as data sources.

4.1.1 NAMSO 4790 Series

Several reports in the NAMSO 4790 series were used in the study. The reports were provided by the Navy Maintenance Support Office, Mechanicsburg, PA. NAMSO was very responsive to all data requests. Specific reports received were:

- Electronic Equipment Performance Report (4790.S6242)
- Material History Report (4790.S5704)
- Steaming and Operating Report (4790.S5763)

The Electronic Equipment Performance Report provides maintenance data and performance measurements by specific equipment serial number for all three AN/SPS-48 EICs. (See Table 4-1 for those data elements extracted.) The Material History Report provides a detailed display of shipboard maintenance data and presents a complete maintenance history of the radar, including the cause of the equipment malfunctions and the parts used to correct the casualties. The Steaming and Operating Report provides the monthly steaming hours for all ships analyzed in the study.

4.1.1.1 Electronic Equipment Performance Report (4790.S6242)

This report is a very useful data source for obtaining organizational resource expenditures. The report is broken down by unit for each of the three radar EICs. Data pertinent to the study contained in the report are the organizational man-hours expended and the total dollar value of the parts expended for each reported maintenance action. The report also details the time spent awaiting parts to support the radar that are on order from the supply system.

The S6242 report was used as the primary source of organizational resource expenditures. Information contained in all NAMSO reports was

Table 4-1

RESOURCES/READINESS DATA SOURCES

Reports/Souces	Use: Readiness	Use: Resource Expenditures	Use: Operating Intensity	Availability
NAMSO 4790 Series Navy Maintenance Support Office Mechanicsburg, PA		• Organizational man-hours(P) • Organizational parts ($)(P) • Time awaiting parts (TWP)(P)	• Steaming hours(P)	
Consolidated CASREP Reports SPCC, Mechanicsburg, PA	• System down time (P)	• Downtime - maintenance (P) • Downtime - supply (TWP) (P)		
Shipyard Departure Reports NAVSEA 9315		• Depot man-hours (P) • Depot materials($)(P)		
NAVSECNORDIV NSN Availability Analyses NAVSECNORDIV		• Organizational parts($)(P) • Organizational man-hours(P)	• Steaming hours(P)	
Commanding Officer's Narrative (CONAR) NSWSES, Port Hueneme, CA	• Significant system casualties(S)		• Op schedule(S)	
AN/SPS-48 Shipboard Reliability Support Program Quarterly Reports ITT/GILFILLAN NAVSEA 62X31	• System operating time(P)			
FORSTAT Reports OP-643			• Underway hours(S)	

(P)-Primary Source
(S)-Secondary Source

compiled from OPNAV Form 4790/2K, NAVSUP Form 1250, and DD Form 1348; documents submitted via the 3-M Maintenance Data System (MDS). This makes the validity of the NAMSO data dependent upon inputs from fleet maintenance personnel. Based on fleet experience, there are some common problems associated with the MDS which make the NAMSO data somewhat suspect.

For example, it is common for a shipboard technician (particularly in an electronics rating) to stock frequently used spares and repair parts separately from designated operating space items (OSI). Thus, he avoids having to stop work to fill out the required paperwork to draw a particular item during troubleshooting and repair of equipment. When this situation occurs, actual demand and usage data are not generated within the Maintenance Data System.

Another factor contributing to inaccuracies in MDS-generated reports is the transcription error rate inherent in any system with such a large volume of handwritten inputs. Numerous line entries in the reports contain obvious errors. Examples of such errors could be easily documented to illustrate this point. Despite the drawbacks inherent in the system, however, the MDS and the reports it generates are among the most accurate sources of data used in the study.

4.1.1.2 Material History Report (4790.S5704)

This report provides a detailed accounting of all shipboard maintenance actions on the AN/SPS-48 Radar, including the specific documented causes of equipment malfunctions and the parts used to correct them. It is a particularly voluminuous report and the data contained therein are summarized by the Electronic Equipment Performance Report (4790.S6242). Therefore, it was used for checking data in S6242 reports and for examining the list of individual parts used for validating individual maintenance actions that were suspect in the summary report (because of extremely high man-hour or dollar expenditures).

4.1.1.3 Steaming and Operating Report (4790.S5763)

This report provides the primary source of monthly steaming hours data for the ships in the study. These data were used in the specific trend analyses of the effects of ship operating intensities on AN/SPS-48 system readiness. The report displays all steaming hours/operating intensity data by month for all ships during the period of the study.

4.1.2 Consolidated Casualty Reporting System (CASREP) Reports

Information from the Consolidated CASREP System was used as the primary study source of radar system downtime. The specific report used was the CASREP Data General Retrieval (SUP 4400.28-6) obtained from the Ships Parts Control Center (SPCC), Mechanicsburg, PA. This report contained all reported AN/SPS-48 Radar casualties on the ships under study during the period from 1 January 1971 through 30 June 1979. Pre-1971 data were unavailable and are not part of SPCC's data base. The report divides downtime into supply downtime and maintenance downtime components. (These two quantities were analyzed in terms of the two readiness definitions. See Sections 5.2.4 and 5.2.5). The report contains C2, C3, and C4 CASREPs, all of which were used in establshing radar downtimes for each system.

On the surface it would appear that the CASREP system is a highly reliable data source. Unfortunately, despite some stringent efforts on the part of fleet and type commanders, certain problems with the CASREP system existed in the past and, in some cases, persist. (Interviews conducted with officers who recently completed CO or XO tours confirm the existence of these problems.) The problem lies with a belief in the fleet that material condition of the ship is directly proportional to the commanding officer's fitness. Because of this perception, which was more pervasive in the early 70's than it is now, casualties that occur which can be corrected without submitting a CASREP often go unreported. The commanding officer who does not anticipate using a particular piece of defective equipment for a length of time sufficient to repair it, will, in some cases, not submit a CASREP. This reluctance leads to lower downtime statistics and fewer casualties reported than actually occurred.

4.1.3 Shipyard Departure Reports

Shipyard Departure Reports, provided by NAVSEA 9315, were used to determine depot-level manpower and material expenditures on the AN/SPS-48 Radars aboard ships under study. The reports covered Regular Overhaul (ROH) periods and certain shorter shipyard availabilities.

There are some difficulties in using the departure reports. Since the study was seeking costs and manpower expenditures on corrective maintenance rather than on system conversion and modifications, a determination of work accomplished during the shipyard periods had to be made from the departure reports. The description of the work is often obscure or unclear, thus complicating the data assembly task. In addition to this problem, departure report statistics are often inaccurate because of budget balancing manipulations that are performed during an overhaul to compensate for differences between job estimates and actual expenditures.

4.1.4 NAVSECNORDIV Analyses

NAVSECNORDIV maintains extensive Maintenance Data Collection System (MDCS) files on systems/equipments over which they have cognizance. These files cover the period from 1 January 1976 through the present. Numerous MDCS data analysis reports are available and several were examined as possible data sources for use in the study. The following reports, provided by NAVSECNORDIV, were analyzed:

- NSND 4790.M7148 - System/Equipment RM&A Cost Analysis Summaries
- NSND 4790.M7108.A01 - Monthly Figure of Merit Indices
- NSND 4790.M7108.B01 - Reliability Analysis Matrix
- NSND 4790.M7108.C01 - Maintainability Analysis Matrix
- NSND 4790.M7275 - RM&A Indices by Hull
- NSND 4790.M6278 - Steaming Hour Matrix
- NSND 4790.M76E1 - Alteration-Cancellation Actions

- NSND 4790.M76E4 - Maintenance Actions Not Corrective Maintenance Actions

- NSND 4790.B78C01 - CASREP Parts History.

The data contained in these reports were reviewed and compared to similar reports from NAMSO and SPCC. Because all three activities use MDS documentation as the source of data contained in their respective maintenance history files, the various reports contained duplicative information, albeit in differing formats, depending on how the data were manipulated.

Two of the reports, the Steaming Hour Matrix and the CASREP Parts History, were used as secondary sources of data on operating tempo and CASREP supply parts information. Of the remaining reports, the RM&A-related indicators were not used, due to their reliance on arithmetic means with no statistical bias or normalization applied, to develop reliability and availability indices. These mean time data definitions were not suitable for use in developing the readiness measures considered in the study (see Section 2.3). However, the trends in reliability and availability indicated by these reports were compared to the trends developed in the analyses utilized in the performance of the study.

The Steaming Hour Matrix (NSND 4790.M7278) reports were used as a secondary data source for tracking the ship's operating profiles and for comparison with other sources used for tracking op tempo data (CONAR, FORSTAT, NAMSO). As previously mentioned, these data were similar to that provided by NAMSO. The CASREP Parts History reports were used to check those reports on SPS-48 Radar CASREPs provided by SPCC, and again proved to be identical in content.

Pre-1976 data analyses were not received due to the extensive and costly efforts that would be required to recatalog and transcribe these data back into NAVSECNORDIV's automated data file. Efforts to assemble these data were not undertaken when it became apparent that the data elements were available from other sources.

4.1.5 Commanding Officer's Narrative Reports (CONAR)

The Commanding Officer's Narrative Reports were provided by the Naval Ship Weapon Systems Engineering Station (NSWSES), Port Hueneme, CA. Due to the narrative format of the CONARs, data extraction was a time-consuming process. However, data contained therein were used as a secondary source of operating tempo information and aided in the identification of critical manning deficiencies on individual units. The CONARs also report significant system casualties and were used to corroborate CASREP data provided by SPCC.

CONARs were not available for all units under study, and the reports for FY75 through FY77, although sent by NSWSES, were never received. The unavailability of data on all systems during the period covered by the study caused CONARs to be used as a secondary corroborative data source.

4.1.6 AN/SPS-48 Shipboard Reliability Support Program Quarterly Reports

The Reliability Support Program Quarterly Reports are generated by the vendor of the AN/SPS-48 Radar, ITT/Gilfillan, Van Nuys, CA, and were provided by NAVSEA 62X31. Information contained in the reports is taken from the Daily System Operation and Maintenance Logs (DSOML) provided by each ship with an AN/SPS-48 Radar. Since the DSOMLs are not a mandatory report to be submitted by each ship, there are some gaps in the data base when ships neglected to submit reports. Ships which neglected to submit these reports, it could reasonably assumed in some cases, possibly were too busy repairing their radar to allow the technicians sufficient time to submit them. This situation has been substantiated when a comparison of CASREP time frames to missing reports was made.

The quarterly reports were used as the primary study source of radar operating time. The reports display the cumulative operating time of each of the subsystems comprising the AN/SPS-48 Radar for each discrete radar set. The operating hours for each subsystem are obtained from the DSMOL entries and are correlated with time meter readings where these entries are available. The reports also reflect cumulative downtime for each subsystem. These downtime data were not used, due to the questionable definition of downtime used by ITT/Gilfillan in generating their reports.

The operating hours, or radar uptime, were taken from the cumulative readings of the Receiver and Power Supply column of Table II of the report. Both the vendor and NAVSEA 62X31 recommended that this set of operating times be used as the "radar operating time" in the study.

According to ITT/Gilfillan reliability section personnel, downtime in their report excludes logistics delay time (time awaiting parts), administrative delay time (time during which the technician is on watch, liberty, sleeping, etc.), and time spent awaiting the procurement of tools and test equipment. ITTG also factors out the time the radar is not operating (i.e., secured), even though this may be the result of a system casualty. This downtime definition cannot be used in calculations of R_1 and R_2 in the study since actual radar downtime is not included in this total. In addition to to the inability of this study to use this downtime figure, there is potential for inflating the value of operational availability (A_0) unless the ITT/Gilfillan definition is fully understood. The full implications of these special downtime definitions have not been comprehensively considered in this study because the statistics were unusable for calculating R_1 and R_2.

An additional problem with the quarterly reports lies in the fact that they have not been issued quarterly in many cases, despite their title. They have been published at irregular intervals ranging up to 6 months between reports. Because of this lack of regularity, some problems in data base assembly resulted in that data taken from other reports had to be adjusted to correspond to the radar operating time taken from the ITT/Gilfillan reports.

ITTG's reports, despite some problems, do have some merit. Appendix II of the reports contains selected correspondence between fleet technicians and ITTG reliability experts. This section allows direct data exchange between the operators of the AN/SPS-48 Radar and vendor technical representatives, and provides valuable troubleshooting and maintenance tips to the shipboard technician.

4.1.7 FORSTAT Reports

FORSTAT reports were provided by OPNAV-643. The initial request for data asked for all available FORSTAT reports related to the AN/SPS-48 Radar on the applicable ships. Two reports were received in response to this request. The reports included the following information:

- Overall unit combat systems ratings (all shipboard combat systems)
- Degraded condition explanation codes (awaiting spare parts; down for modification, etc.)
- Unit Anti-Air Warfare (AAW) ratings
- Degraded condition explanation codes.

Information provided covered the period from 1 January 1975 through 31 December 1979. Data on all air-search radars were provided, rather than on just the AN/SPS-48, thus complicating data assembly and analysis. Each line entry in the reports listed the unit, the beginning and ending date of the system degradation, the overall and equipment rating, and a reason for the degradation (i.e., awaiting parts, inoperative, undergoing unscheduled maintenance).

On the surface this appeared to be a very strong data source; however, numerous problems with the information included in the reports with other data sources proved to be a severe problem. These problems are discussed in Section 4.2.

OPNAV-643 was also tasked with providing a listing of the number of underway days and in-port days, by quarter, using the FORSTAT data base as a source. This report was provided for 1 January 1976 through 30 June 1979. Pre-1976 data were not available in the FORSTAT historical data files. Data contained proved to be inaccurate and substantially unusable for study purposes.

4.2 Problems with Data Received

There were several problems that had to be solved relating to the data that were received. This section discusses some of these problems and presents the decisions that were made to adjudicate these problems in the study. The major problem with the data received was the inconsistencies noted in specific data elements found in more than one source. The two areas that were impacted most heavily by these inconsistencies were: (1) unit operating time; and (2) radar downtime. Both quantities were essential to the two readiness measures used in the study.

4.2.1 Unit Operating Time

When reviewing the data sources for determining individual unit operating time, many instances were noted where the underway time for a given unit during a particular quarter was listed as one quantity in the NAMSO Steaming and Operating Report, a second different value in the operating schedule of the CONAR, and yet a third value in the FORSTAT operating tempo report. In other instances, like quantities would agree in two of the three sources, or similar elements would differ when found in two sources.

Because of the previously mentioned inaccuracies in the FORSTAT data (see Section 4.1.7) and the lack of CONARs on all units over the entire period of the study (see Section 4.1.5), the data contained in the NAMSO reports were used as the primary data source for unit operating time. The NAVSECNORDIV M6278 Steaming Hour Matrix (see Section 4.1.4) corroborated the NAMSO data and was a determining factor in the decision to use the NAMSO reports as the primary data source.

4.2.2 Radar Downtime

Another major difficulty we encountered was in the determination of system downtime. The ITT/Gilfillan-generated Reliability Support Program Reports downtime determinations were invalid due to the assumptions used in calculating these data (see Section 4.1.9). The only source of downtime data were the CASREP reports, which, as indicated, tend to understate the actual system downtime experienced.

This problem was further complicated by the fact that the AN/SPS-48 is capable of transmitting in several modes (first stage, second stage, driver, and final), albeit at varying levels of operational capability. This, of course, makes a specific downtime determination more difficult. For example, is the radar "down" when it is capable of transmitting through the driver stage in which it has approximately 90% of its operational capability, or is it "down" when it can only radiate through the second stage which gives a 55-65% operational capability?

According to the AN/SPS-48 project engineer, NAVSEA (62X31), there are no concrete guidelines established for CASREP severity determinations. This determination is left to the discretion of each unit's commanding officer.

The resolution of the problem of downtime determination was inherent in the decision to use the CASREP reports as the primary source of downtime data. The reports used contain all CASREPs of the AN/SPS-48. All measurements of performance degradation (C-2, 3, 4) are included in these reports and were counted as downtime for the study, thereby alleviating the problem of having to differentiate between varying degrees of system degradation.

Whenever possible, the CASREP downtime data determinations were corroborated with other data sources (i.e., NAMSO parts and man-hour expenditures, CONARs). Despite the inbred bias which characterizes the CASREP system, explained in Section 4.1.5, the CASREP reports provide the best available source of system downtime data.

4.3 Data Unavailability

This section of the report will detail areas of the study which suffered from a lack of available data. Three areas which were originally to have been examined as part of the study were subsequently deleted due to a lack of usable data. The three areas are:

- The impact of training on readiness
- The impact of personnel distribution in the fleet on readiness
- The impact of intermediate level maintenance and vendor support on readiness.

4.3.1 AN/SPS-48 Training

In the process of preparing to begin work on the study, contact was made informally with the AN/SPS-48 Class "C" Schools at Dam Neck and Mare Island. Through information received during the informal contacts, a request was made for lists of "C" school graduates, the NECs the graduates attained, and the ships to which they reported were requested through CNTT. Official correspondence from CNTT reported that the data was unavailable. With this basic data unavailable, the impact of training on readiness could not be tested, even in the cursory fashion that was anticipated. Thus, this section had to be deleted from the study.

4.3.2 Personnel Distribution

During initial phases of the study it was determined that a possible correlation existed between the individual ship manning posture (in support of the AN/SPS-48) and readiness. The information desired was the historical track of the number of authorized SPS-48 technician billets versus the number of bodies filling those billets. Due to some serious problems with computerized data bases at NMPC, reconstruction of the historical track of all ships being considered was estimated to be a 6-9 month task. Thus, on a detailed level, this area was abandoned.

There were, however, data available on a Navy-wide basis. That is, a historical track of billets versus bodies for the entire Navy for the applicable NECs was available covering the period from October 1974 to the present. These data were provided by NMPC 472 (see Section 5.1.5).

4.3.3 Intermediate-level Maintenance/Vendor Support

A third area which was hampered by the unavailability of data was the effect of resource expenditures at the intermediate level upon system readiness. COMNAVSURFLANT and COMNAVLOGPAC are the commands with cognizance over the MOTU units on the East Coast and West Coasts respectively. COMNAVSURF-LANT could only provide the sum of the MOTU man-hours expended on the East Coast units for the period January 1973 through June 1979. These figures could not be broken down on a quarterly basis to correspond to the periods examined in the study. COMNAVLOGPAC provided the same data for the period July 1978 through June 1979 for West Coast MOTU resource expenditures. COMNAVLOGPAC recently instituted a computerized data system to gather this type of MOTU expenditure information. Prior to July 1978, reassembly of data involves a very complex effort.

The other source of intermediate-level support, NAVSECNORDIV, maintains no readily available data base of the manpower expenditures on the radar. ITT/Gilfillan, the radar vendor, also does not maintain a record of man-hour expenditures, despite providing substantial support to the fleet in maintaining the radar. The lack of these data precluded tne assessment of the impact of these resource expenditures on system readiness.

5.0 STATISTICAL ANALYSIS

Section 3.0, Analytical Approach, presented an overview of the general statistical methodology pursued in this investigation. In view of the lack of apparent relationships (determined from visual inspection of the scatter diagrams) between most of the variables under consideration, it was decided to run complete statistical analyses on all variables. The analyses performed are:

- Coefficient of Correlation (Pearson Product Moment Coefficient)
- Coefficient of Determination
- Linear Regression Equation (Slope and Intercept)
- Significance Measures (Estimate, Slope, and Intercept)
- Standard Errors (Estimate, Slope, and Intercept).

These statistics were calculated for the following variable pairs:

- Readiness (R_1 and R_2) versus Organizational Man-hours
- Readiness (R_1 and R_2) versus Depot Man-hours and Depot Parts Expenditures
- Readiness (R_1 and R_2) versus Organizational Parts Expenditures
- Readiness (R_1 and R_2) versus Maintenance Personnel Availability
- Readiness (R_1 and R_2) versus Actual Radar Operating Time
- Readiness (R_1 and R_2) versus Estimated Radar Operating time
- Readiness (R_1 and R_2) versus Ship Operating Intensity (using actual radar operating time)
- Readiness (R_1 and R_2) versus Ship Operating Intensity (using estimated radar operating time)
- Readiness (R_1 and R_2) versus Time Awaiting Parts
- Readiness (R_1 and R_2) versus Maintenance Downtime
- Readiness (R_1 and R_2) versus Supply Downtime
- Readiness (R_1 and R_2) versus Calendar Time.

The remainder of Section 5.0 discusses the results of statistical analysis of the aforementioned variables. The results for each variable set are reported in the following standardized format:

- Introduction - A brief discussion of the variables being analyzed
- Observations
  - -- Visual Trends - discerned from scatter diagrams
  - -- Strength of Variate Correlation - analysis of the Pearson Product Moment correlation coefficient
  - -- Direction of Correlation/Slope of Regression Line
  - -- Statistical Significance of Regression Slope
- Conclusions.

Table 5-28 summarizes the results of the various trend analyses.

5.1 Readiness Versus Resources

5.1.1 Readiness Versus Organizational Man-hour Expenditures

5.1.1.1 Scatter Diagrams Run to Test the Sensitivity of Readiness and Organizational Man-hour Expenditures

Two sets of scatter diagrams were developed to examine the relationship between readiness and organizational man-hour expenditures. The two runs were:

- R_1 versus organizational man-hour expenditures
- R_2 versus organizational man-hour expenditures.

Organizational man-hour expenditures represent the hours spent by fleet technicians in performing corrective maintenance on the radar. The corrective maintenance man-hours expended during each reporting period were derived primarily from the NAMSO 4790 report series with NAVSECNORDIV reports used as a secondary data source. (See Sections 4.1.1 and 4.1.4). The organizational man-hour expenditure values depicted in the scatter diagrams range from 0-2000 man-hours (X-axis). The definition of R_1 and R_2 and the data sources used to calculate these values are discussed in Section 2.3. The range of values displayed in the scatter diagrams is from 0-1 for the readiness measures (X-axis).

5.1.1.2 Observation - R_1 Versus Organizational Man-hour Expenditures

- Visual Trends - Visual inspection of the 60 R_1 vs. Organizational Man-hour Expenditures scatter diagrams (Table 5-1) yields no apparent pattern of strong linear, non-linear, or curvilinear trends. Over 90% of the scatter diagrams exhibit an almost total random distribution of the data points. Scatter diagram C3V illustrates the distribution exhibited in most of the diagrams. (See Appendix B-1).

- Strength of Variate Correlation - As depicted in Table 5-1 the strength of correlation between the two variables (readiness and organizational man-hour expenditures) is not statistically significant. The strongest correlation among the variables is -.950 for system C18C and this system has only four plotted data points. This diagram is presented in Appendix B-2.

- Direction of Correlation - The correlations show a fairly equal distribution of the direction of the correlations (27 negative, 33 positive), which indicates no trend toward increasing readiness with increasing man-hour expenditures.

- Significance of Slope
The only scatter diagram with a significance value of 0.05 or less is C18C.

5.1.1.3 Observations R_2 Versus Organizational Man-hour Expenditures

- Visual Trends - Visual analysis of the 60 scatter diagrams in this diagram run (see Table 5-2 for a tabulated summary) showed no discernable relationship between R_2 and organizational man-hour expenditures. In over 90% of the scatter diagrams, readiness appears to be randomly distributed over the range of resource expenditures. The scatter diagram for system D7A is typical of the majority of the diagrams in this program run. (See Appendix B-3).

- Strength of Variate Correlation - Table 5-2 indicates no statistically significant correlation between readiness and organizational man-hour expenditures. The strongest correlation coefficient exhibited is -.970 for system C6C (5 data points) reproduced in Appendix B-4.

- Direction of Correlation - 33 of the 60 scatter diagrams have negative correlation coefficiencies indicating an inverse relationship between R_2 and man-hour expenditures.

- Significance of Slope - Two scatter diagrams have significance values less than 0.05, one with a positive slope and one with a negative slope.

TABLE 5-1

TITLE: R1 vs. Organizational Level Man-hour Expenditures

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	.043	.00011	.865
A1 V	.159	.00096	.684
A3 A	-.173	-.00030	.378
A4 A	-.163	-.00035	.504
A4 C	-.750	-.00101	.250
A4 V	-.008	-.00003	.989
A5 A	-.257	-.002	.356
A5 V	-.068	-.00019	.825
A6 C	.246	.00018	.639
A6 V	.391	.00098	.065
A7 C	-.543	-.00043	.265
A7 V	.400	.002	.058
A9 A	.149	.00023	.556
A9 V	-.197	-.00035	.562
A11A	.080	.00013	.753
A11V	-.040	-.00007	.907
A13A	-.016	-.00007	.956
A13V	.351	.002	.166
B1 A	.601	.002	.066
B1 V	.233	.00044	.284
B2 V	-.256	-.00060	.197
B3 A	-.449	-.001	.094
B3 V	.195	.001	.503
B4 V	-.192	-.00037	.327
B6 C	-.121	-.00038	.819
B6 V	.108	.00037	.625
B7 A	-.017	-.00012	.955
B7 V	.157	.00032	.534
C1 A	-.048	-.00006	.911
C3 A	.180	.00093	.520
C3 C	.106	.00016	.894
C3 V	.135	.00031	.711
C4 A	.371	.003	.130
C4 V	.035	.00014	.924
C5 V	.604	.003	.064
C6 A	-.558	-.002	.047
C6 C	-.259	-.00034	.674
C8 A	-.181	-.00071	.554
C8 V	.161	.00078	.551
C9 A	.015	.00004	.953
C9 V	-.510	-.005	.197

TABLE 5-1 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C12A	.097	.00030	.618
C13A	.237	.005	.376
C13V	.681	.004	.021
C14V	.273	.001	.177
C15A	.397	.00025	.256
C15V	-.127	-.00048	.605
C17V	-.189	-.00031	.453
C18C	-.950	-.008	.050
C18V	.051	.00009	.810
D2 V	.343	.00071	.118
D4 V	-.374	-.002	.104
D5 A	.357	.00040	.103
D6 A	-.207	-.00097	.367
D7 A	-.011	-.00001	.957
E2 A	.264	.00033	.614
E2 C	.653	.004	.347
E3 A	.780	.008	.220
E3 C	-.454	-.009	.366
E5 A	.166	.00030	.626

TABLE 5-2

TITLE: R2 vs. Organizational Level Man-hour Expenditures

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	-.230	-.00084	.357
A1 V	-.182	-.00145	.637
A3 A	-.176	-.00048	.368
A4 A	-.493	-.0013	.031
A4 C	-.749	-.00101	.250
A4 V	.085	.00028	.872
A5 A	-.148	-.00154	.596
A5 V	.206	.00062	.498
A6 C	.515	.0004	.294
A6 V	.085	.00009	.696
A7 C	-.778	-.00097	.068
A7 V	.109	.00037	.619
A9 A	.070	.00008	.780
A9 V	-.481	-.0005	.133
A11A	.145	.00034	.563
A11V	.036	.00007	.915
A13A	.025	.00012	.931
A13V	-.136	-.00059	.600
B1 A	.603	.00253	.064
B1 V	.009	.00001	.965
B2 V	-.239	-.00064	.228
B3 A	-.583	-.0017	.022
B3 V	-.108	-.00053	.711
B4 V	-.173	-.0004	.376
B6 C	-.124	-.00045	.814
B6 V	-.487	-.00074	.018
B7 A	-.084	-.00077	.774
B7 V	.179	.00053	.476
C1 A	-.461	-.00031	.249
C3 A	.219	.001	.431
C3 C	.114	.00018	.885
C3 V	-.689	-.00118	.027
C4 A	.153	.001	.672
C4 V	-.458	-.00203	.055
C5 V	.058	.00015	.871
C6 A	-.697	-.00259	.008
C6 C	-.970	-.0009	.0059
C8 A	-.167	-.001	.583
C8 V	-.332	-.0013	.208
C9 A	-.197	-.00053	.417
C9 V	-.331	-.004	.422

TABLE 5-2 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C12A	-.061	-.00022	.752
C13A	.281	.004	.290
C13V	.448	.00261	.166
C14V	-.100	-.00036	.626
C15A	.278	.00032	.436
C15V	.003	.00001	.989
C17V	-.176	-.00051	.483
C18C	.949	.012	.050
C18V	-.503	-.00087	.010
D2 V	-.037	-.00008	.866
D4 V	-.452	-.0034	.045
D5 A	.288	.00043	.193
D6 A	-.067	-.00055	.771
D7 A	.001	.194	.995
E2 A	.126	.00002	.811
E2 C	.107	.00082	.892
E3 A	.281	.00068	.718
E3 C	-.587	-.021	.219
E5 A	.204	.00034	.546

5.1.1.4 Conclusions

A logical assumption to make in performing analyses of readiness versus organizational man-hour expenditures is to expect readiness to improve after the expenditure of organizational man-hours on that system. The analysis in Section 5.1.1 did not support this assumption. There were no strong linear correlations developed and the vast majority of scatter diagrams run yielded inconclusive results. Although a very slight trend exists towards increased readiness with increased organizational man-hour expenditures, this trend occurs with much less frequency than is necessary to demonstrate a quantitative correlation.

5.1.2 Readiness Versus Organizational Parts Expenditure

5.1.2.1 Scatter Diagrams Run to Test the Sensitivity of Readiness and Organizational Parts Expenditures

Two sets of scatter diagrams were developed to examine the relationship between readiness and organizational parts expenditures. The two runs are:

- R_1 versus organizational parts expenditures
- R_2 versus organizational parts expenditures.

Organizational parts expenditures represent the dollars spent by fleet units on parts required to perform maintenance on the radar. As noted in Section 2.4.1 the dollars expended have been adjusted for inflation over the 10-year period of interest. The parts expended during each reporting period were derived primarily from the NAMSO 4790 reort series with NAVSECNORDIV reports used as a secondary data source. (See Sections 4.1.1 and 4.1.4.) The organizational parts expenditure values depicted in the scatter diagrams range from $0-250,000 (X-axis). The definition of R_1 and R_2 and the data sources used to calculate these values are discussed in Section 2.3. The range of values displayed in the scatter diagrams is from 0-1 for the readiness measures (X-axis).

5.1.2.2 Observations - R_1 Versus Organizational Parts Expenditure

- Visual Trends - Visual analysis of the 56 scatter diagrams of R_1 versus Organizational Parts Expenditures yielded no discernable linear, non-linear, or curvilinear relationships. The majority of the diagrams exhibit a random scatter but a few do suggest a negatively sloped pattern. No fleet or configuration patterns are apparent. Appendices B-5 and B-6 are typical scatter diagrams from this data set.

- Strength of Variate Correlation - Table 5-3 lists the radars and their associated correlation coefficients, slopes, and significance values. Inspection of the table reveals that only two (2) of the systems have correlation coefficients > .7 (or < -.7).

- Direction of Correlation - Slope of Regression Line - Both of the systems with large correlation coefficients have negative slopes while, overall, 25 of 59 have negative slopes. This indicates that there is not a strong trend towards either a direct or inverse relationship between readiness and organizational parts expenditures.

- Significance of Slope - Neither of the two highly correlated systems have significance values less than 0.05.

5.1.2.3 Observations - R_2 Versus Organizational Parts Expenditures

- Visual Trends - Visual analysis of the other readiness measure, R_2, yields the same results as for R_1; no discernable linear, non-linear, or curvilinear pattern is apparent. Appendices B-7 and B-8 are typical scatter diagrams from this data.

- Strength of Variate Correlation - Table 5-4 lists the correlation coefficients, slopes, and significant values for all the scatter diagrams in this group. Only five out of the 59 scatter diagrams have correlation coefficients > .7 (or < -.7). This empirical data suggests that there is not a very strong linear relationship.

- Direction of Correlation - Slope of Regression Line - Three of the five highly correlated scatter diagrams have negative slopes and two are positive. Overall, 34 of 59 have negative slopes. This inconsistency in the slope is further evidence that there is no linear relationship between R_2 and Organizational Parts Expenditures.

- Significance of Slope - Three of the five scatter diagrams with large correlation coefficients have significance values less than 0.05. Using this criteria only three of 59 scatter diagrams show a linear relationship with a distinguishable slope and, of these, two have negative slopes and one has a positive slope.

5.1.2.4 Conclusions

Based on the observation that less than 10% of the data sets have high correlation coefficients, the conclusion must be made that a linear relationship does not exist between readiness as defined and Organizational Parts Expenditures. The inconsistency of the slopes also supports this conclusion.

TABLE 5-3

TITLE: R1 vs. Organizational Parts Expenditure

RADAR	CORRELATION (R)	SLOPE	SIGNIFICANCE (R)
A1 A	.040	.172E-06	.874
A1 V	.250	.321E-05	.517
A3 A	-.225	-.188E-05	.249
A4 A	.130	.968E-06	.597
A4 C	-.637	-.582E-06	.363
A4 V	.320	.310E-05	.537
A5 A	-.055	-.365E-06	.847
A5 V	-.215	-.205E-05	.481
A6 C	.594	.344E-05	.291
A6 V	.220	.224E-05	.314
A7 C	-.622	-.131E-05	.187
A7 V	.367	.526E-05	.085
A9 A	.020	.982E-07	.939
A9 V	.178	.138E-05	.600
A11A	.386	.290E-05	.126
A11V	-.140	-.255E-05	.681
A13A	.029	.189E-06	.922
A13V	.473	.851E-05	.055
B1 A	.291	.171E-05	.414
B1 V	.195	.206E-05	.373
B2 V	-.351	-.814E-05	.072
B3 A	-.094	-.240E-05	.750
B3 V	-.083	-.277E-05	.778
B4 V	-.366	-.203E-05	.056
B6 C	-.583	-.183E-05	.224
B6 V	.167	.286E-05	.446
B7 A	.139	.111E-05	.635
B7 V	-.384	-.213E-05	.115
C1 A	.142	.104E-05	.762
C3 A	.352	.342E-05	.198
C3 C	.263	.369E-06	.737
C3 V	.101	.840E-06	.782
C4 A	.064	.498E-06	.862
C4 V	.113	.106E-05	.655
C5 V	.601	.00002	.066
C6 A	-.529	-.665E-05	.063
C6 C	-.751	-.00001	.249
C8 A	-.098	-.406E-06	.750
C8 V	.240	.326E-05	.371
C9 A	-.080	-.101E-05	.745
C9 V	-.555	-.551E-05	.153

TABLE 5-3 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C12A	-.173	-.132E-05	.369
C13A	-.358	-.543E-05	.173
C13V	.379	.457E-05	.250
C14V	.051	.643E-06	.806
C15A	-.181	-.593E-06	.667
C15V	.547	.506E-05	.015
C17V	-.283	-.463E-05	.254
C18C	-.943	-.275E-05	.057
C18V	.190	.154E-05	.375
D2 V	.303	.281E-05	.171
D4 V	-.163	-.150E-05	.492
D5 A	.385	.291E-05	.077
D6 A	.193	.134E-05	.430
D7 A	.109	.855E-06	.587
E2 A	.217	.00003	.679
E3 A	-.026	-.156E-06	.974
E3 C	.300	.752E-06	.564
E5 A	-.133	-.416E-06	.696

TABLE 5-4

TITLE: R2 vs. Organizational Parts Expenditures

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	-.276	-.170E-05	.267
A1 V	-.138	-.232E-05	.722
A3 A	-.282	-.367E-05	.145
A4 A	.004	.409E-07	.985
A4 C	-.636	-.582E-06	.363
A4 V	.405	.730E-05	.425
A5 A	.017	.173E-06	.950
A5 V	-.238	-.247E-05	.432
A6 C	.019	.145E-06	.974
A6 V	-.324	-.131E-05	.131
A7 C	-.768	-.253E-05	.074
A7 V	.001	.137E-07	.994
A9 A	-.153	-.536E-06	.555
A9 V	.006	.290E-07	.984
A11A	.345	.385E-05	.174
A11V	-.136	-.254E-05	.689
A13A	.074	.557E-06	.799
A13V	-.147	-.189E-05	.573
B1 A	.345	.221E-05	.328
B1 V	-.418	-.293E-05	.046
B2 V	-.257	-.679E-05	.195
B3 A	-.115	-.321E-06	.694
B3 V	.160	.376E-05	.582
B4 V	-.323	-.214E-05	.092
B6 C	-.590	-.215E-05	.217
B6 V	-.552	-.414E-05	.006
B7 A	.087	.874E-06	.765
B7 V	-.425	-.346E-05	.078
C1 A	.152	.522E-06	.743
C3 A	.289	.399E-05	.295
C3 C	.270	.391E-06	.729
C3 V	-.827	-.518E-05	.003
C4 A	.095	.118E-05	.792
C4 V	-.486	-.279E-05	.040
C5 V	.120	.191E-05	.739
C6 A	-.407	-.478E-05	.166
C6 C	-.258	-.678E-06	.741
C8 A	.027	.170E-06	.929
C8 V	-.233	-.262E-05	.384
C9 A	-.330	-.420E-05	.167
C9 V	-.340	-.470E-05	.409

TABLE 5-4 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C12A	-.434	-.377E-05	.018
C13A	-.105	-.136E-05	.696
C13V	.163	.194E-05	.630
C14V	-.371	-.398E-05	.061
C15A	-.317	-.189E-05	.444
C15V	-.145	-.129E-05	.551
C17V	-.362	-.00001	.138
C18C	.952	.396E-05	.047
C18V	-.435	-.343E-05	.033
D2 V	.183	.173E-05	.412
D4 V	-.168	-.217E-05	.477
D5 A	.316	.318E-05	.151
D6 A	.185	.220E-05	.446
D7 A	.025	.280E-06	.898
E2 A	-.840	-.00002	.036
E3 A	.785	.106E-05	.214
E3 C	.259	.124E-05	.619
E5 A	-.073	-.206E-06	.829

5.1.3 Readiness Versus Depot Man-hour and Depot Parts Expenditures

5.1.3.1 Data Assembled to Test Readiness Over Depot Man-hour and Depot Parts Expenditures

Table 5-5 was assembled to summarize the relationship between readiness and depot-level man-hour and parts expenditures. The readiness measures for all systems with reported depot-level man-hour and parts expenditures were examined for the four reported periods immediately following the period during which the expenditures occurred.

The definitions of R_1 and R_2 and the data sources used to calculate these values are contained in Section 2.3. The data sources used to compile the depot-level expenditures are discussed in Section 4.1.3. The man-hour and cost data listed in Table 5-5 are for work other than modifications or field change installations, i.e., they represent corrective maintenance expenditures only.

5.1.3.2 Observations on R_1 and R_2 Versus Depot Man-hour and Parts Expenditures

- Visual Trends - Table 5-5 lists all depot-level man-hour expenditures reported on the units under study, and tracks the two readiness measures for the period during which the expenditure occurred and the four periods immediately following the expenditures, if available. These data were examined to determine if any trends in readiness were observable after depot resources had been expended.

Examination of the data reveals a definite decreasing trend in system readiness in the reporting periods immediately following a depot resource expenditure. In the first period after the expenditure of depot resources the value of R_1 decreased in 17 cases, increased in ten cases, and remained the same in nine cases (as compared to the R_1 value for the period in which the depot expenditures occurred). The data for R_2 showed 18 values decreasing, eight increasing, and ten remaining the same.

Examination of the second period after the period during which the expenditures occurred showed a definite trend towards improved readiness as the values of R_1 increased in 14 cases, decreased in 16 cases, and remained the same in five cases, when compared to the values for the first period after depot expenditure. For R_2, 14 values increased, 15 decreased and six remained the same. During the third period following depot expenditures, the trend towards increased readiness continued as the R_1 values increased in 18 cases, decreased in eight, and remained the same in four instances, when compared to the second period after the expenditures. R_2 increased for 17 systems, decreased for eight, and remained constant for five during the same period.

TABLE 5-5

TITLE: Readiness and Corresponding Depot Resource Expenditures

SYSTEM	REPORT	DEPOT MAN-HOUR EXPENDITURES	DEPOT PARTS EXPENDITURES	R1	R2
C12A	12	488	0	.64	.64
	13	0	0	1.00	1.00
	14	0	0	1.00	1.00
	15	8408	24709	1.00	1.00
	16	0	0	1.00	1.00
	17	0	0	1.00	1.00
	18	0	0	1.00	1.00
	19	0	0	.42	.37
	36	4624	89974	.89	.92
	37	0	0	1.00	1.00
A9 V	12	7672	118881	.92	.93
	13	0	0	1.00	1.00
	14	0	0	.80	.81
	15	0	0	.61	.57
	16	0	0	.43	.71
A11V	17	3776	32466	1.00	1.00
	18	0	0	1.00	1.00
	19	0	0	.93	.98
A11A	20	0	0	1.00	1.00
	21	0	0	.46	.26
A4 A	15	10648	24525	.76	.85
	16	0	0	1.00	1.00
	17	0	0	.48	.08
	18	0	0	.50	.00
	19	0	0	.24	.00
A4 C	35	13072	157011	1.00	1.00
	36	0	0	1.00	1.00
	37	0	0	.92	.92
A5 V	18	1048	54615	1.00	1.00
	19	0	0	.98	.99
	20	0	0	.91	.94
	21	0	0	.95	.97
	22	0	0	.39	.01
A5 A	37	3016	13851	1.00	1.00
A3 A	10	16656	173799	1.00	1.00
	11	0	0	1.00	1.00
	12	0	0	.99	.99
	13	0	0	1.00	1.00
	14	0	0	.39	.00

TABLE 5-5 Cont.

TITLE: Readiness and Corresponding Depot Resource Expenditures

SYSTEM	REPORT	DEPOT MAN-HOUR EXPENDITURES	DEPOT PARTS EXPENDITURES	R1	R2
C17V	35	720	6312	.73	.76
	36	3024	25238	1.00	1.00
	37	0	0	1.00	1.00
B7 V	19	608	313	.88	.91
	20	0	0	.48	.31
	21	0	0	.95	.97
	22	0	0	1.00	1.00
	23	0	0	1.00	1.00
C4 V	27	3952	40860	1.00	1.00
	28	0	0	1.00	1.00
	29	0	0	.67	.51
	30	0	0	.58	.51
	31	0	0	1.00	1.00
D2 V	34	3296	85015	1.00	1.00
D2 C	35	0	0	1.00	1.00
	36	0	0	1.00	1.00
	37	0	0	1.00	1.00
C13V	18	11944	49251	.65	.66
	19	0	0	.39	.00
	20	0	0	.24	.34
	21	0	0	.35	.04
	22	0	0	1.00	1.00
D7 A	20	2856	0	.76	.79
	21	0	0	.92	.95
	22	0	0	.31	.02
	23	0	0	.59	.45
	24	0	0	.64	.48
C9 A	17	7360	30759	.67	.81
	18	0	0	.58	.32
	19	0	0	.73	.74
	20	0	0	.67	.47
	21	0	0	.70	.55
A[illegible] C	33	21240	118679	.65	.77
	34	0	0	.13	.47
	35	0	0	.87	.78
	36	0	0	.61	.45
	37	0	0	.48	.01

TABLE 5-5 Cont.

TITLE: Readiness and Corresponding Depot Resource Expenditures

SYSTEM	REPORT	DEPOT MAN-HOUR EXPENDITURES	DEPOT PARTS EXPENDITURES	R1	R2
C15A	28	14864	185399	1.00	1.00
	29	0	0	.56	.25
	30	0	0	.63	.59
	31	0	0	.50	.08
	32	0	0	.61	.26
B6 V	14	4480	32540	.96	.99
	15	0	0	.57	.59
	16	0	0	.69	.63
	17	0	0	1.00	1.00
	18	0	0	.85	.86
A1 V	17	14136	52331	.50	.37
	18	0	0	.40	.06
	19	0	0	.59	.07
	20	0	0	.74	.68
	21	0	0	.45	.08
C14V	10	11664	105492	.94	.96
	11	0	0	.65	.65
	12	0	0	.72	.75
	13	920	1080	.67	.69
	14	0	0	.67	.69
	15	0	0	.46	.05
	16	0	0	.90	.93
	17	0	0	.93	.96
	34	13224	154335	.50	.37
	35	0	0	.50	.37
	36	0	0	.13	.26
	37	0	0	1.00	1.00
C1 A	32	536	9510	.76	.82
	33	0	0	.92	.91
	34	0	0	.47	.57
	35	0	0	.81	.79
	36	0	0	.66	.60
C6 A	23	528	2882	1.00	1.00
	24	0	0	.71	.39
	25	0	0	1.00	1.00
	26	0	0	1.00	1.00
	27	0	0	1.00	1.00

TABLE 5-5 Cont.

TITLE: Readiness and Corresponding Depot Resource Expenditures

SYSTEM	REPORT	DEPOT MAN-HOUR EXPENDITURES	DEPOT PARTS EXPENDITURES	R1	R2
C18V	32	3688	68819	.64	.64
	33	0	0	.42	.12
	34	0	0	.07	.56
	35	0	0	.43	.17
	36	0	0	.34	.00
E3 A	31	1596	16468	.39	.00
E3 C	32	0	0	.47	.00
	33	0	0	.45	.00
	34	0	0	.39	.02
	35	0	0	.69	.40
A13V	23	1240	881	1.00	1.00
A13A	24	0	0	.28	.67
	25	0	0	.73	.88
	26	0	0	1.00	1.00
	27	0	0	1.00	1.00
B1 V	27	4280	39993	1.00	1.00
B1 A	28	0	0	.35	.54
	29	0	0	.38	.12
	30	0	0	.95	.96
B3 V	19	1056	905	.00	.57
	20	6344	5727	1.00	1.00
	21	0	0	1.00	1.00
	22	3040	35242	1.00	1.00
	23	0	0	.52	.42
	24	0	0	1.00	1.00
	25	0	0	1.00	1.00
	26	0	0	1.00	1.00
C3 A	19	12080	38964	.13	.55
	20	0	0	.43	.23
	21	0	0	.62	.74
	22	0	0	.44	.00
	23	0	0	.36	.00

TABLE 5-5 Cont.

TITLE: Readiness and Corresponding Depot Resource Expenditures

SYSTEM	REPORT	DEPOT MAN-HOUR EXPENDITURES	DEPOT PARTS EXPENDITURES	R1	R2
D5 A	19	240	0	.74	.76
	20	0	0	.66	.60
	21	0	0	.74	.77
	22	0	0	.87	.81
	23	0	0	1.00	1.00
D6 A	17	7016	53214	.79	.83
	18	0	0	1.00	1.00
	19	72	6261	1.00	1.00
	20	0	0	.51	.09
	21	0	0	.45	.00
	22	0	0	.54	.47
	23	0	0	1.00	1.00
C8 V	24	15576	114929	1.00	1.00
C8 A	25	0	0	1.00	1.00
	26	0	0	.49	.10
	27	0	0	.45	.20
	28	0	0	.47	.16
C5 A	20	1280	1549	.73	.78
	21	0	0	.42	.47
	22	0	0	.54	.45
	23	0	0	1.00	1.00
	24	0	0	.72	.76

In the fourth period after the depot-level expenditures, R_1 increased in 11 cases, decreased in 13 and remained constant in four, compared to the third period after the expenditures. For the same period, R_2 increased for 11 systems, decreased for 11, and remained the same for six. These figures are illustrated in Table 5-6.

Table 5-6

Readiness Trends During Periods Following Overhaul

	R_1			R_2		
Period	Increase	Decrease	No Change	Increase	Decrease	No Change
T + 1	10	17	9	8	18	10
T + 2	14	16	5	14	15	6
T + 3	18	8	4	17	8	5
T + 4	11	13	4	11	11	6

5.1.3.3 Conclusions

The observed tendency of system readiness to be degraded immediately following a large expenditure of depot resources and rebound during the next two periods can be attributed to the "burn-in" characteristic exhibited by electronic equipment which has not operated for a considerable period or has undergone major rework or modification. Readiness indicators generated during this "infant mortality" period are discounted by the equipment vendor ITT/Gilfillan, in their reliability calculations. They disregard all failures occuring during the 3 months immediately following any major availabili during which work is performed in the SPS-48. Another factor that may be contributing to this trend is the large personnel turnover which usually occurs during a lengthy yard period. A relatively inexperienced crew is more likely to incur casualties to the system and will take longer to troubleshoot and repair system malfunctions.

The readiness indicators generated by this study clearly show a trend towards increased readiness in the second and third quarters following a major depot resource expenditure. Although not demonstrative of a resource to readiness correlation this trend should be recognized by operational planners and commanders.

5.1.4 Readiness Versus Personnel Availability

5.1.4.1 Readiness Trends Versus Personnel Availability

Three tables corresponding to the three system configurations under analysis were developed to examine the relationship between system readiness and maintenance personnel availability. The three tables were:

- Readiness versus Personnel Availability for the SPS-48A(V)

- Readiness versus Personnel Availability for the SPS-48C(V)
- Readiness versus Personnel Availability for the SPS-48(V).

The definitions of R_1 and R_2 and the data sources used to derive their numerical values are found in Section 2.3. The figures for the percentage of billets filled for each of the three radar configurations (A.C,V) were calculated from data obtained from the microfiche files supplied by NMPC 472. The only maintenance personnel figures available were gross Navy-wide billets detailed versus authorized billet totals from October 1974 through the present. These data do not exist in a form from which the authorized billets versus the actual billets assigned on a unit level can be extracted. (See Section 4.3.2).

5.1.4.2 Observations of Readiness and Personnel Availability for the AN/SPS-48C(V)

- Visual Trends - Due to the relatively short period of time (six reporting periods) for which data for the SPS-48C can be drawn from the available information, it would appear that there is a slight trend in increased readiness. The increase is in the number of technicians with the applicable NEC detailed to the existing billets. This apparent trend has no statistical significance in view of the limited time frame for which data is available. (See Table 5-8.)

5.1.4.3 Observations on Readiness and Personnel Availability for the AN/SPS-48A(V)

- Visual Trends - Personnel availability for the SPS-48A(V) has increased at a steady level to a point for the last month covered by the study (June 1979), the manning level of NEC 1136 was 170% of the authorized billets. When Table 5-7 is analyzed there appears to be no significant correlation between the two variables from periods 18 through 29. In period 30, however, when the manning level reaches 65.5%, through period 37, the significant increases in the manning levels are accompanied by a general trend in increased system readiness.

  Although these data cover a relatively short time frame, a case can be made that, as the number of technicians assigned to Navy units increases with a concurrent increase in the experience level and training, the readiness of the system will improve.

5.1.4.4 Observations on Readiness and Personnel Availability for the AN/SPS-48(V)

- Visual Trends - The personnel availability for AN/SPS-48(V), the original radar variant, has experienced a general downward trend (See Table 5-9). As more units are being modified to the (A) and (C) configurations, more personnel are being trained to support the later modifications. Beginning with report period 26 when the first significant reductions in billet strength began, there has been a slight trend towards decreased system readiness. The decreased personnel availability undoubtedly contributes to this trend, but it cannot be statistically correlated with the data available. It must also be realized that as more units undergo conversion to the (A) or (C) modification, personnel with the (A) or (C) NECs could be assigned to units with the (V) configuration so that the number of personnel assigned to (V) units may be proportionally equal to the numbers assigned to units with the two latest modifications.

5.1.4.5 Conclusions

There appears to be a slight trend towards increased readiness with increased personnel availability for units with the SPS-48A and SPS-48C configuration; however, due to limitations in the available data, it is difficult to make a strong statistical correlation between the two variables. Increased personnel availability no doubt makes a significant contribution to increased system readiness, but the increased readiness can also be attributed to the increase in the experience level of the technicians who have had time to become familiar with the new systems. Another factor contributing to improved readiness is the increased supply support available after a new system has been introduced to the fleet.

Unfortunately, a quantitative relationship between readiness and personnel availability cannot be conclusively shown within the scope of this study. However, the trends look favorable enough to be considered as a source for future study, more narrowly focused on the training/personnel availability area of resource expenditures.

TABLE 5-7

TITLE: Readiness vs. Personnel Availability (SPS-48C(V))

PERIOD	PERCENTAGE OF BILLETS FILLED	R1 (Avg)	R2 (Avg)
32	3.4%	.67	.76
33	3.0%	.49	.71
34	19.9%	.67	.67
35	22.6%	.77	.68
36	25.9%	.63	.76
37	33.9%	.75	.87

TABLE 5-8

TITLE: Readiness vs. Personnel Availability (SPS-48A(V))

PERIOD	PERCENTAGE OF BILLETS FILLED	R1 (Avg)	R2 (Avg)
18	30.3%	.77	.87
19	36.7%	.65	.69
20	42.7%	.71	.67
21	45.5%	.59	.60
22	51.3%	.68	.68
23	49.5%	.72	.79
24	46.8%	.72	.70
25	42.8%	.75	.78
26	46.1%	.76	.73
27	49.5%	.65	.67
28	51.8%	.65	.62
29	54.0%	.68	.61
30	65.5%	.69	.75
31	87.0%	.80	.79
32	95.4%	.75	.76
33	95.9%	.77	.78
34	107.6%	.75	.75
35	146.4%	.85	.87
36	165.0%	.83	.84
37	168.0%	.79	.80

TABLE 5-9

TITLE: Readiness vs. Personnel Availability (SPS-48(V))

PERIOD	PERCENTAGE OF BILLETS FILLED	R1 (Avg)	R2 (Avg)
18	79.6%	.79	.84
19	69.0%	.70	.73
20	71.9%	.78	.81
21	77.3%	.78	.89
22	75.8%	.73	.81
23	75.6%	.78	.84
24	83.6%	.81	.88
25	85.1%	.82	.95
26	78.7%	.76	.80
27	73.5%	.90	.95
28	69.9%	.95	.96
29	65.5%	.79	.90
30	60.5%	.75	.86
31	72.7%	.90	.96
32	56.2%	.68	.79
33	50.5%	.70	.74
34	33.6%	.72	.80
35	40.3%	.62	.57
36	43.3%	1.00	1.00
37	43.3%	1.00	1.00

5.2 Readiness Versus Other Factors

5.2.1 Readiness Versus Time

5.2.1.1 Readiness Trends Over Time

Four sets of scatter diagrams were developed to examine readiness trends over time. The four program runs were:

- R_1 (with estimated radar operating time) versus calendar time (period midpoint days)
- R_2 (with estimated radar operating time) versus calendar time (period midpoint days)
- R_1 (with actual radar operating time only) versus calendar time (period midpoint days)
- R_2 (with actual radar operating time only) versus calendar time (period midpoint days).

The definition of R_1 and R_2 and the data sources used to derive their numerical values are found in Section 2.3.

The period covered by the study (1 January 1970 - 30 June 1979) has been divided into 37 periods, roughly corresponding to the periods during which ITT/Gilfillan has generated AN/SPS-48 Radar Reliability Support Reports. These reports constitute the primary source of radar operating time data (see Section 4.1.8). The time line used to generate the R_1/R_2 vs. time scatter diagrams represents the cumulative number of days from the beginning of the period covered by the study to the midpoint of the period for which R_1 and R_2 were calculated. The range of values depicted in the scatter diagrams are 0-1 for the readiness measures (Y-axis) and 400-3500 for the period midpoint days (time) plotted along the X-axis.

Two sets of radar operating time were used in this analysis. The actual values of radar operating time were derived from the ITT/Gilfillan reports as explained in Section 4.1.9. The estimated values were calculated for periods during which the data was unavailable in the ITT/Gilfillan reports which had significant gaps in data reporting.

In order to calculate the estimated radar operating time, a multiplier was defined using actual ship operating time and actual radar operating time as reported in the ITT/Gilfillan reports. A mean ratio was established using the known quantities, then used as a multiplier with actual ship operating time to obtain an estimate of the unreported radar operating time values. These values were then used in calculating the values of R_1 and R_2 for the first two sets of scatter diagrams.

5.2.1.2 Observations - R_1 (With Estimated Radar Operating Time) Versus Time

- Visual Trends - Visual analysis of the 60 scatter diagrams yielded no apparent linear, non-linear, or curvilinear trends over time

TABLE 5-10

TITLE: R1 vs. Time

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	-.112	-.00008	.681
A1 V	-.279	-.00008	.504
A3 A	-.626	-.00024	.00037
A4 A	.167	.00010	.509
A4 C	-.727	-.00022	.273
A4 V	.418	.00050	.410
A5 A	.536	.00030	.040
A5 V	-.052	-.00003	.872
A6 C	.169	.00020	.748
A6 V	-.125	-.00004	.609
A7 C	-.511	-.00052	.301
A7 V	.265	.00010	.258
A9 A	-.366	-.00015	.148
A9 V	-.485	-.00033	.131
A11A	.168	.00010	.506
A11V	.586	.00039	.058
A13A	.316	.00027	.272
A13V	-.067	-.00004	.820
B1 A	.503	.00045	.138
B1 V	-.538	-.00021	.026
B2 V	.066	.00003	.750
B3 A	.083	.00005	.770
B3 V	-.214	-.00023	.553
B4 V	.108	.00001	.592
B6 C	.729	.00060	.100
B6 V	.601	.00018	.007
B7 A	.353	.00028	.215
B7 V	.542	.00025	.020
C1 A	-.772	-.00097	.025
C3 A	.821	.00072	.00017
C3 C	-.844	-.00092	.156
C3 V	.592	.00045	.161
C4 A	-.081	-.00005	.824
C4 V	-.103	-.00013	.826
C5 A	.442	.00022	.075
C5 V	-.123	-.00011	.771
C6 A	-.116	-.00010	.720
C6 C	.924	.002	.025
C8 A	-.016	-.00001	.958
C8 V	.634	.00035	.027
C9 A	.421	.00018	.082

TABLE 5-10 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C9 V	.612	.00071	.107
C12A	.333	.00026	.266
C13A	.547	.00042	.043
C13V	-.284	-.00015	.427
C14V	-.148	-.00005	.511
C15A	.090	.00005	.805
C15V	-.322	-.00010	.243
C17V	.706	.00031	.001
C18C	.862	.001	.138
C18V	.226	.00009	.324
D2 V	.074	.005	.763
D4 V	.124	.00005	.603
D5 A	-.290	-.00013	.202
D6 A	-.048	-.00002	.836
D7 A	.138	.00004	.483
E2 A	-.142	-.00006	.820
E2 C	-.891	-.002	.109
E3 C	.856	.00091	.029
E5 A	.222	.00009	.511

for the radar systems examined. A substantial majority of the scatter diagrams showed a completely random distribution of the data points (see Table 5-10). The scatter diagram for radar serial A6V (see Appendix B-9) is representative of the random distribution exhibited by most of the 53 diagrams.

- Strength of Variate Correlation - As depicted in Table 5-10 there exists no strong or significant correlation between R_1 and calendar time. Although ten of the 60 scatter diagrams have correlation coefficients with absolute values greater than .7, most of these diagrams have six or fewer data points, thus making the calculations statistically suspect. The highest linear correlation exists for system C6C with a correlation of .924. As can be seen in Appendix B-10 there are only five data points reported.

- Direction of Correlation - The 60 scatter diagrams show an almost equal distribution (29 positive, 31 negative) of the direction of their regressed slopes, thereby indicating no apparent fleet-wide trend toward increasing or decreasing readiness over time. Analysis of trends over time at the configuration level (48V, 48A, 48C) and fleet-level rendered no discernable readiness trends over time.

- Significance of Slope - Of the ten scatter diagrams with correlation coefficients of seven or better, five have significance values less than 0.05.

5.2.1.3 Observations - R_2 (With Estimated Radar Operating Time) Versus Time

- Visual Trends - Visual analysis of the 60 individual R_2 time trends yielded no readily apparent pattern of significant linear, non-linear, or curvilinear correlation. The majority of the scatter diagrams exhibited a completely random distribution of readiness values over the time period of interest. Analysis of system readiness over time indicates no trend at the aggregate, fleet, or configuration level. The scatter diagram for radar C18V is presented in Appendix B-11 as representative of the distribution observed in most of the 60 scatter diagrams.

- Strength of Variate Correlation - Inspection of Table 5-10 which lists the correlation coefficient, slope, and significance of the 60 regressions run for R_2 vs. time reveals no significant correlations between the variable pair. Nine of the 60 scatter diagrams have correlation coefficients with an absolute value greater than .7 (eight of the nine have eight or fewer data points). The strongest correlation exists for system E2C with a correlation coefficient of -.954, but as can be seen in Appendix B-12 only four data points are plotted.

- Direction of Correlation - Regression Slope of the 60 scatter diagrams are divided between positive and negative directions (26 negative, 34 positive), thus indicating no consistent trend towards increasing or decreasing readiness over time.

TABLE 5-11

TITLE: R2 vs. Time

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	.161	.00017	.549
A1 V	-.519	-.00036	.187
A3 A	-.622	-.00037	.0004
A4 A	.261	.00022	.293
A4 C	-.726	-.00022	.273
A4 V	.395	.00048	.437
A5 A	.512	.00042	.050
A5 V	-.157	-.00013	.624
A6 C	-.626	-.00084	.182
A6 V	-.596	-.00024	.0404
A7 C	-.531	-.00085	.277
A7 V	.267	.00011	.253
A9 A	-.353	-.00016	.163
A9 V	-.242	-.0001	.473
A11A	.133	.00012	.598
A11V	.536	.00037	.088
A13A	.179	.00017	.538
A13V	-.142	-.00009	.627
B1 A	.484	.00047	.155
B1 V	-.341	-.00017	.180
B2 V	-.011	-.580	.954
B3 A	.032	.00002	.908
B3 V	-.762	-.00077	.0103
B4 V	.058	.945	.771
B6 C	.684	.00066	.133
B6 V	.526	.00019	.052
B7 A	.337	.00033	.238
B7 V	.467	.00031	.0502
C1 A	-.815	-.0005	.013
C3 A	.551	.00068	.033
C3 C	-.840	-.00095	.159
C3 V	.671	.00078	.098
C4 A	-.193	-.0002	.592
C4 V	.179	.00009	.558
C5 A	.451	.00023	.068
C5 V	.244	.00023	.558
C6 A	-.215	-.00023	.525
C6 C	.471	.00057	.423
C8 A	.075	.00008	.806
C8 V	.584	.00046	.045
C9 A	.387	.00024	.111

TABLE 5-11 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C9 V	.667	.00137	.332
C12A	-.107	-.00005	.5927
C13A	.752	.00091	.012
C13V	.807	.00055	.192
C14V	.026	.00002	.928
C15A	.194	.00021	.590
C15V	-.599	-.00051	.066
C17V	.682	.00054	.0018
C18C	-.941	-.00185	.058
C18V	.00098	.518	.996
D2 V	-.109	-.00007	.654
D4 V	.190	.00111	.422
D5 A	-.207	-.0015	.365
D6 A	-.048	-.00004	.834
D7 A	-.330	-.00015	.132
E2 A	-.141	-.00005	.820
E2 C	-.954	-.0025	.045
E3 C	.912	.0018	.011
E5 A	.212	.00008	.554

- Significance of Slope - Of the nine diagrams with correlation coefficients > .7 or < -.7, five have significance values of less than 0.05. Three of these have negative and two have positive slopes, further indicating no linear pattern exists in this data.

5.2.1.4 Observations on R_1 (With Actual Radar Operating Time Only) Versus Time

- Visual Trends - Visual analysis of the 60 scatter diagrams showed a slight tendency toward a more significant degree of linear correlation than the previous two program runs; however, the majority of the diagrams displayed a completely random distribution of the data points. The scatter diagrams for system A1A is representative of the random distribution exhibited by a large portion of the 60 diagrams. (See Appendix B-13.)

- Strength of Variate Correlation - No significant correlation is apparent upon examination of the data in Table 5-11. Fifteen of the 60 scatter diagrams have correlation coefficients with absolute values greater than .7 (12 of the 15 have eight or fewer data points). The strongest correlation between readiness and time was exhibited by system E3C with a correlation coefficient of .936 (five variable pairs are plotted). (See Appendix B-14.)

- Direction of Correlation - Although 31 of the 53 scatter diagrams exhibit positive slopes and therefore seem to indicate a trend towards increasing system readiness over time, the lack of significant correlation and large standard errors in the regression equations do not statistically support this conclusion.
- Significance of Slope - Seven of the 15 scatter diagrams with high correlation have significant values less than 0.05. Thus, using the established criteria, only seven of the 53 exhibit a linear relationship with a slope distinguishable from zero (0).

5.2.1.5 Observations - R_2 (With Actual Radar Operating Time Only) Versus Time

- Visual Trends - Visual inspection of readiness trends over time provides no discernable pattern among the systems examined. As in the previous runs, the majority of the scatter diagram display a random distribution of data points. The scatter diagrams for system B3A is representative of the random distribution observed. (See Appendix B-15.)

- Strength of Variate Correlation - The correlation coefficients listed in Table 5-13 indicate no apparent linear correlation between readiness and calandar time. Only seven of the 60 scatter diagrams have correlation coefficients with absolute values greater than seven. The strongest correlation exhibited by any of the systems in this run is -.924, for system E2C with only four data points. (See Appendix B-16.)

TABLE 5-12

TITLE: R1 vs. Time

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	-.112	-.00008	.681
A3 A	-.179	-.00009	.507
A4 A	.167	.00010	.509
A4 C	-.727	-.00022	.273
A5 A	.252	.00018	.430
A5 V	.780	.001	.220
A6 C	.169	.00020	.748
A6 V	-.387	-.00018	.214
A7 C	-.511	-.00052	.301
A7 V	.485	.00034	.130
A9 A	-.366	-.00015	.148
A9 V	-.390	-.00037	.339
A11A	.218	.00013	.417
A13A	.316	.00027	.271
A13V	.617	.00052	.00033
B1 A	.503	.00045	.38
B1 V	-.098	-.00006	.801
B2 V	.543	.00037	.036
B3 A	.083	.00005	.770
B3 V	-.270	-.00036	.518
B4 V	.472	.00010	.048
B6 C	.729	.00060	.100
B6 V	.539	.00019	.047
B7 A	.353	.00028	.215
C1 A	-.772	-.00097	.025
C3 A	.781	.00078	.002
C3 C	-.844	-.00092	.156
C4 A	-.081	-.00005	.824
C4 V	.042	.00002	.890
C5 A	.432	.00021	.123
C5 V	-.703	-.001	.297
C6 A	-.125	-.00010	.713
C6 C	.924	.002	.025
C8 A	-.016	-.00001	.958
C8 V	.304	.00027	.558
C9 A	.421	.00018	.082
C9 V	.814	.001	.186
C12A	-.071	-.00002	.724
C13A	.819	.00081	.004
C13V	.865	.00052	.135
C14V	-.050	-.00003	.864

TABLE 5-12 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C15A	.090	.00005	.805
C15V	-.374	-.00016	.287
C17V	.856	.00069	.014
C18V	.882	.00044	.00001
D2 V	.091	.00016	.847
D4 V	-.643	-.00058	.062
D5 A	-.211	-.00010	.386
D6 A	.110	.00005	.655
D7 A	-.281	-.00010	.205
E2 C	-.891	-.002	.109
E3 C	.936	.00086	.019
E5 A	.192	.00008	.595

TABLE 5-13

TITLE: R2 vs. Time

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	.162	.00017	.550
A3 A	-.406	-.00036	.118
A4 A	.262	.00022	.294
A4 C	-.727	-.00022	.273
A5 A	.307	.00035	.332
A5 V	.780	.002	.220
A6 C	-.627	-.00084	.183
A6 V	-.213	-.00005	.382
A7 C	-.532	-.00085	.277
A7 V	.469	.00036	.146
A9 A	-.354	.00016	.164
A9 V	-.012	-.629E-05	.978
A11A	.189	.00018	.483
A13A	.180	.00017	.539
A13V	.202	.00019	.702
B1 A	.485	.00047	.155
B1 V	-.078	-.00007	.842
B2 V	.358	.00033	.190
B3 A	.032	.00002	.909
B3 V	-.760	-.00056	.029
B4 V	.438	.00012	.069
B6 C	.685	.00066	.133
B6 V	.597	.00019	.007
B7 A	.337	.00033	.238
C1 A	-.815	-.00054	.014
C3 A	.430	.00063	.142
C3 C	-.841	-.00095	.159
C4 A	-.193	-.00020	.593
C4 V	.005	.505E-05	.991
C5 A	.422	.00020	.133
C5 V	-.541	-.00056	.459
C6 A	-.205	-.00022	.523
C6 C	.471	.00057	.423
C8 A	.075	.00008	.807
C8 V	.346	.00024	.502
C9 A	.388	.00024	.112
C9 V	.518	.00084	.188
C12A	.233	.00028	.444
C13A	.497	.00046	.070
C13V	-.413	-.00033	.236
C14V	-.197	-.00009	.380
C15A	.194	.00021	.591
C15V	-.567	-.00032	.027
C17V	.534	.00054	.217

TABLE 5-13 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C15A	.194	.00021	.591
C15V	-.567	-.00032	.027
C17V	.534	.00054	.217
C18V	.604	.00040	.010
D2 V	-.110	-.00007	.654
D4 V	-.438	-.00043	.238
D5 A	-.138	-.00010	.574
D6 A	.123	.00010	.615
D7 A	.208	.00009	.288
E2 C	-.954	-.003	.046
E3 C	.947	.002	.014
E5 A	.222	.00008	.512

- Direction of Correlation - As with the previous R_1 vs. time run, a majority (32 of 53) of the scatter diagrams exhibit a positive slope and tend to point to a trend in increasing system readiness over time. However, the lack of a significant trend in correlation does not support this hypothesis.

- Significance of Slope - Four of the scatter diagrams with high correlation coefficients have significant values less than 0.05.

5.2.1.6 Conclusions

The four program runs made to observe the system readiness over time produced no evidence of any statistically significant trends. The systems were examined on both a macro (all 60 systems) and micro (configuration, fleet grouping) level and no strong statistical correlations were present.

5.2.2 Analysis of Readiness Versus Ship Operational Intensity

5.2.2.1 Scatter Diagrams Run to Test the Sensitivity of Readiness and Ship Operational Intensity

Four sets of scatter diagrams were developed to examine the relationship between radar readiness, as defined by R_1 and R_2, and ship operational intensity (OI). The four runs are:

- R_1 (using actual radar operating time) versus OI

- R_2 (using actual radar operating time) versus OI

- R_1 versus OI (using estimated radar operating time)

- R_2 versus OI (using estimated radar operating time).

The definitions and derivation explanation of R_1 and R_2 are found in Section 2.3. An explanation of the estimated radar operating times used in calculating the readiness measures is found in Section 5.2.1.1. The ship operational intensity was calculated for each reporting period using the NAMSO 4790 report series to obtain ship operational time. (These operational times were validated by comparing the NAMSO data to available Commanding Officers' Narrative Reports.) (See Sections 4.1.1 and 4.1.5.)

Operational intensity for each period was calculated by dividing the actual ship operational time by the total time in each reporting period. The range of values depicted in the scatter diagrams (X-axis) is zero (0) to one (1) for operational intensity, reflecting the proportion of time the ship was underway during each of the reporting periods.

5.2.2.2 Observations - R_1 (Using Actual Radar Operating Time) Versus Ship Operational Intensity

- Visual Trends - Visual examination of the scatter diagrams yields no discernable overall pattern relating readiness and operating intensity. There are several patterns present, but overall, there

TABLE 5-14

TITLE: R1 vs. Operational Intensity

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	.453	.812	.078
A3 A	.372	.322	.216
A4 A	.188	.275	.456
A4 C	-.051	-.020	.949
A4 V	-1.000	-.721	
A5 A	-.838	-1.310	.162
A5 V	-.391	-.714	.234
A6 C	.370	-.355	.236
A6 V	.089	.225	.867
A7 C	.188	.167	.559
A7 V	-.467	-.768	.350
A9 A	-.218	-.261	.401
A9 V	.545	.660	.162
A11A	.035	.043	.896
A13A	.239	.316	.411
A13V	-.611	-.715	.197
B1 A	.317	.708	.372
B1 V	.402	.414	.283
B2 V	-.131	-.206	.642
B3 A	.424	.648	.116
B3 V	.046	.075	.914
B4 V	.237	.161	.343
B6 C	.253	.419	.628
B6 V	-.196	-.228	.502
B7 A	-.194	-.662	.507
C1 A	-.525	-1.002	.182
C3 A	.367	1.072	.217
C3 C	.049	.062	.951
C3 V	1.000	.364	
C4 A	-.337	-.416	.342
C4 V	-.091	-.216	.846
C5 A	.399	.708	.158
C5 V	.326	.465	.674
C6 A	.180	.226	.596
C6 C	.616	1.671	.269
C8 A	.168	.315	.583
C8 V	-.050	-.058	.925
C9 A	.218	.232	.384
C9 V	-.241	-.395	.759
C12A	-.679	-.980	.011
C13A	-.120	-.172	.741

TABLE 5-14 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C13V	-.848	-.245	.152
C14V	-.611	-.792	.020
C15A	-.660	-.737	.038
C15V	.006	.010	.988
C17V	-.469	-.663	.289
C18C	-.989	-.903	.096
C18V	-.379	-.557	.134
D2 V	.638	1.368	.123
D4 V	-.247	-.293	.523
D5 A	-.014	-.023	.954
D6 A	-.445	-.534	.056
D7 A	.184	.223	.418
E2 C	.186	.390	.814
E3 A	.689	1.505	.516
E3 C	-.380	-.579	.528
E5 A	-.086	-.062	.814

seems to be a random distribution. Appendices B-17 and B-18 display scatter diagrams typical of this program run.

- Strength of Variate Correlation - Table 5-13 lists the correlation and regression measures associated with the R_1 vs. OI data set. Only two systems have correlation coefficients with absolute values greater than 0.7, and, it should be noted that, for these two cases the measures are derived from only four data points. o

- Direction of Correlation - Slope of Regression Line - Both of the systems noted above have negative slopes. Overall, 27 of the 53 diagrams have negative slopes, further indicating that no trend exists.

- Significance of Slope - Neither of the two systems with high correlation coefficients have significance values less than 0.05.

5.2.2.3 <u>Observations - R_2 (Using Actual Radar Operating Time) Versus Ship Opertional Intensity</u>

- Visual Trends - Visual analysis of the scatter diagrams reveals no linear or non-linear pattern present. (See Appendix B-19 and B-20 for typical examples.)

- Strength of Variate Correlation - Table 5-15 lists the correlation coefficients, the slopes, and the significance values associated with each of the data sets. Four of the 53 correlation coefficient's absolute values are greater than 0.70.

- Direction of Correlation - Slope of Regression Line - Of the four values noted above, three have negative slopes. Thirty-four of the 53 scatter diagrams have negative slopes, giving a slight indication of an inverse relationship between readiness and operating intensity.

- Significance of Slope - Of the four data sets with high correlation coefficients, one with a positive slope and one with a negative slope have significance values less than 0.05.

5.2.2.4 <u>Observations - R_1 (Using Estimated Radar Operating Time) Versus Ship Operational Intensity</u>

- Visual Trends - Visual inspection reveals no pattern evident throughout the data; however, the majority of the scatter diagrams exhibit random distribution. Appendices B-21 through B-23 are typical examples of the diagrams in this run.

- Strength of Variate Correlation - Table 5-16 lists the correlation and regression measures associated with each set of data. Only one set has a correlation coefficient with an absolute value greater than 0.7. This coefficient is derived from only six data points.

TABLE 5-15

TITLE: R2 vs. Operational Intensity

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	.373	1.02885	.154
A3 A	.101	.18064	.707
A4 A	-.049	-.10201	.844
A4 C	-.050	.01959	.949
A4 V	-1.000	-.591	
A5 A	-.341	-.51178	.277
A5 V	-.838	-1.42879	.161
A6 C	.046	.13406	.931
A6 V	.299	.237	.343
A7 C	-.655	-1.69066	.157
A7 V	-.368	-.734	.264
A9 A	-.217	-.261	.400
A9 V	.730	.503	.039
A11A	-.091	-.165	.737
A13A	.211	.318	.467
A13V	-.678	-.913	.138
B1 A	.259	.633	.832
B1 V	.120	.190	.757
B2 V	-.139	-.298	.619
B3 A	.411	.753	.127
B3 V	.479	.435	.229
B4 V	.358	.316	.143
B6 C	.251	.483	.630
B6 V	-.280	-.336	.331
B7 A	-.219	-.941	.450
C1 A	-.633	-.634	.091
C3 A	.189	.804	.535
C3 C	.052	.068	.947
C3 V	-1.0	-.242	
C4 A	-.420	-.820	.226
C4 V	-.433	-.818	.331
C5 A	.378	.633	.182
C5 V	.025	.019	.974
C6 A	-.142	-.234	.675
C6 C	-.194	-.376	.754
C8 A	.096	.272	.754
C8 V	-.141	-.127	.789
C9 A	.082	.122	.745
C9 V	-.397	-.789	.602
C12A	-.802	-1.77	.00096
C13A	-.157	-.275	.664

TABLE 5-15 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C13V	-.830	-.269	.169
C14V	-.677	-1.29	.00771
C15A	-.497	-1.033	.143
C15V	-.023	-.0804	.948
C17V	-.248	-.446	.590
C18C	.978	1.35	.133
C18V	-.355	.594	.161
D2 V	.563	2.403	.187
D4 V	-.076	-.098	.843
D5 A	-.072	-.183	.766
D6 A	-.397	-.836	.091
D7 A	-.0019	-.00284	.993
E2 C	-.492	-1.36	.507
E3 A	-.500	-.354	.666
E3 C	-.393	-1.23	.511
E5 A	-.061	-.040	.866

TABLE 5-16

TITLE: R1 vs. Operational Intensity

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	.452	.812	.078
A1 V	.217	.147	.604
A3 A	-.087	-.111	.659
A4 A	.187	.274	.455
A4 C	-.050	-.019	.949
A4 V	-.944	-.733	.004
A5 A	-.350	-.389	.199
A5 V	-.399	-.503	.198
A6 C	.088	.224	.867
A6 V	.0102	.01044	.966
A7 C	-.466	-.767	.350
A7 V	-.270	-.441	.248
A9 A	-.215	-.227	.405
A9 V	.344	.391	.299
A11A	.076	.096	.762
A11V	-.315	-.236	.344
A13A	.238	.316	.411
A13V	-.157	-.169	.589
B1 A	.317	.708	.371
B1 V	.503	.387	.033
B2 V	-.189	-.236	.353
B3 A	.423	.647	.115
B3 V	.035	.046	.922
B4 V	-.035	-.022	.856
B6 C	.253	.418	.628
B6 V	-.584	-.628	.008
B7 A	-.193	-.662	.506
B7 V	-.375	-.654	.124
C1 A	-.524	-1.00238	.181
C3 A	-.104	-.227	.711
C3 C	.048	.061	.951
C3 V	-.644	.672	.118
C4 A	-.336	-.415	.341
C4 V	-.199	-.240	.514
C5 A	.232	.281	.368
C5 V	.207	.191	.622
C6 A	.063	.074	.843
C6 C	.615	1.67	.269
C8 A	.167	.314	.583
C8 V	-.462	-.459	.130
C9 A	.218	.232	.383

TABLE 5-16 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C5 V	-.331	-.575	.422
C12A	.567	-.725	.00203
C13A	-.254	-.337	.380
C13V	-.358	-.301	.308
C14V	-.441	-.634	.039
C15A	-.660	-.737	.037
C15V	-.059	-.052	.832
C17V	.232	.236	.353
C18C	-.581	-.474	.468
C18V	-.241	-.357	.291
D2 V	.377	.475	.111
D4 V	-.233	-.273	.344
D5 A	.143	.220	.534
D6 A	-.472	-.587	.030
D7 A	-.004	-.005	.982
E2 A	.398	.183	.506
E2 C	.185	.389	.814
E3 A	.688	1.50	.516
E3 C	-.549	-.832	.259
E5 A	-.061	-.044	.858

TABLE 5-17

TITLE: R2 vs. Operational Intensity

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	.373	1.029	.155
A1 V	.308	.485	.458
A3 A	-.132	-.264	.502
A4 A	-.049	-.102	.844
A4 C	-.051	-.020	.949
A4 V	-.924	-.716	.009
A5 A	-.335	-.550	.222
A5 V	-.244	-.451	.445
A6 C	.046	.134	.931
A6 V	.088	.082	.719
A7 C	-.655	-1.691	.158
A7 V	-.293	-.541	.210
A9 A	-.218	-.261	.401
A9 V	.504	.329	.114
A11A	-.048	-.090	.851
A11V	-.291	-.224	.385
A13A	.212	.318	.468
A13V	-.195	-.209	.505
B1 A	.260	.634	.469
B1 V	.334	.323	.176
B2 V	-.162	-.261	.428
B3 A	.412	.753	.127
B3 V	.420	.521	.227
B4 V	.085	.064	.667
B6 C	.252	.484	.630
B6 V	-.617	-.688	.005
B7 A	-.220	-.941	.451
B7 V	-.056	-.144	.825
C1 A	-.634	-.634	.091
C3 A	-.172	-.531	.540
C3 C	.053	.069	.947
C3 V	-.737	-1.182	.059
C4 A	-.420	-.820	.227
C4 V	-.484	-.520	.094
C5 A	.201	.244	.439
C5 V	.073	.067	.864
C6 A	-.214	-.327	.504
C6 C	-.194	-.377	.754
C8 A	.096	.272	.755
C8 V	-.506	-.712	.093
C9 A	.082	.122	.745

TABLE 5-17 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C9 V	-.397	-.963	.330
C12A	-.615	-1.183	.00063
C13A	-.289	-.469	.315
C13V	-.282	-.363	.430
C14V	-.559	-1.119	.007
C15A	-.497	-1.034	.144
C15V	-.033	-.056	.907
C17V	.379	.683	.121
C18C	.800	.928	.200
C18V	-.252	-.511	.270
D2 V	.368	.852	.121
D4 V	-.172	-.297	.467
D5 A	.094	.227	.685
D6 A	-.426	-.924	.054
D7 A	-.103	-.167	.602
E2 A	.398	.143	.507
E2 C	-.493	-1.362	.507
E3 A	-.500	-.354	.667
E3 C	-.514	-1.487	.297
E5 A	-.046	-.030	.893

- Direction of Correlation - Slope of Regression Line - The one data set with the high correlation coefficient has a negative slope. Overall, 34 of the 60 data sets have negative slopes.

- Significance of Slope - The one set previously noted has a significance value less than 0.05.

5.2.2.5 Observations - R_2 (Using Estimated Radar Operating Time) Versus Ship Operational Time

- Visual Trends - A visual inspection reveals that no linear or nonlinear relationship exists between R_2 and Ship Operational Intensity. Many of the data points do lie along a vertically oriented line, but they are widely scattered. Appendices B-24 through B-26 are typical of the scatter diagrams in this program run.

- Strength of Variate Correlation - Table 5-17 lists the correlation coefficients, the slopes, and the significance values for all sets of data in this run. Three of the sets have correlation coefficients with absolute values greater than 0.70.

- Direction of Correlation - Slope of Regression Line - Of the three data sets mentioned previously, two have negative slopes and, overall, 38 of 60 sets have negative slopes, again indicating a trend in decreasing readiness with increased operating intensity. However, this hypothesis is not supported with strong correlation coefficients and significance values.

- Significance of Slope - One of the data sets with a negative slope and a high correlation coefficient has a significance value less than 0.05.

5.2.2.6 Conclusion

Based on the fact that less than 10% of the systems display high correlation and there is relatively little discernable slope trend, the conclusion must be made that there is no linear relationship between readiness, as defined, and ship operational intensity.

5.2.3 Analysis of Readiness Versus Time Awaiting Parts

5.2.3.1 Scatter Diagrams Run to Test the Sensitivity of Readiness and Time Awaiting Parts

Two sets of scatter diagrams were developed to examine the relationship between readiness and time awaiting parts. The two runs were:

- R_1 versus Time Awaiting Parts

- R_2 versus Time Awaiting Parts.

Time awaiting parts is the number of hours spent waiting for repair parts used to complete a maintenance action, and represents time spent waiting for parts not onboard and for parts requisitioned to replenish onboard stocks. The values for the time spent awaiting for parts were derived primarily from the NAMSO 4790 report series, with NAVSECNORDIV reports used as a secondary data source (see Sections 4.1.1 and 4.1.4). The values depicted in the scatter diagrams for time spent awaiting parts range from 0-2900 hours (X-axis). The definitions of R_1 and R_2 and the data sources used to calculate these values are discussed in Section 2.3. The range of values depicted in the scatter diagrams for the readiness measures are from 0-1 (X-axis).

5.2.3.2 <u>Observations - R_1 Versus Time Awaiting Parts</u>

- Visual Trends - A visual analysis reveals that there is a slight trend in the data toward a negative relationship (i.e., decreased readiness with increased time spent awaiting parts). Many sets reflect this trend and, except for some spurious data points lying along the X-axis, would support a generally negatively sloped pattern. See Appendices B-27 through B-29 for typical examples of these scatter diagrams.

- Strength of Variate Correlation - Table 5-18 lists the correlation and regression measures associated with the data set. Only three scatter diagrams have correlation coefficients with absolute values greater than 0.7. This does not support the conclusion reached visually but, if those spurious points are discarded, the absolute value of the correlation coefficients increase.

  - A9V (Discard 1) -.37 $\rightarrow$ -.72
  - B3A (Discard 3) -.316 $\rightarrow$ -.745

- Direction of Correlation - Slope of Regression Line - Two of the three sets with high correlation coefficients have negative slopes. This result is not supportive of the conclusions made by visual analysis.

- Significance of Slope - Of those sets with high correlation coeffients only one has a significance value less than 0.05.

5.2.3.3 <u>Observations - R_2 Versus Time Awaiting Parts</u>

- Visual Trends - A visual evaluation of this data shows that the same phenomenon exists as observed for R_1 vs. TWP; there is a negative sloped tendency save for a few spurious data points. Appendix B-30 through B-32 are typical examples of the scatter diagrams generated by this data.

- Strength of Variate Correlation - Table 5-19 lists the correlation coefficients, slopes, and significance values associated with each set of data. Only four sets of data have a correlation coefficients with an absolute value greater than 0.7. But, again, if those spurious points are discarded the coefficients improve.

TABLE 5-18

TITLE: R1 vs. Time Waiting Parts

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	-.093	-.00022	.711
A1 V	.440	.00119	.235
A3 A	.183	.00016	.350
A4 A	-.027	-.00002	.912
A4 C	.345	.00002	.654
A4 V	.260	.00012	.618
A5 A	.204	.00023	.464
A5 V	-.621	-.001	.031
A6 C	-.784	-.00053	.064
A6 V	.315	.00018	.141
A7 C	-.478	-.00345	.337
A7 V	.205	.00010	.346
A9 A	.181	.00084	.471
A9 V	-.370	-.00030	.262
A11A	.031	.00001	.900
A11V	-.433	-.00015	.182
A13A	.034	.00002	.907
A13V	.115	.00007	.658
B1 A	.402	.00039	.248
B1 V	.024	.00002	.912
B2 V	-.188	-.00016	.345
B3 A	-.212	-.00013	.447
B3 V	.471	.00070	.088
B4 V	-.102	-.00002	.611
B6 C	.563	.00086	.244
B6 V	.192	.00041	.378
B7 A	.271	.00021	.347
B7 V	.009	.381	.971
C1 A	-.057	-.00091	.892
C3 A	-.109	-.00018	.697
C3 C	.079	.00009	.920
C3 V	.316	.00016	.372
C4 V	.185	.00032	.461
C5 V	.479	.00055	.161
C6 A	-.458	-.0017	.115
C6 C	-.711	-.00062	.178
C8 A	-.331	-.00062	.00053
C8 V	.081	.00016	.764
C9 A	-.121	-.00007	.621
C9 V	.535	.00035	.171
C12A	.019	.00002	.918

TABLE 5-18 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C13A	-.503	-.012	.046
C13V	.586	.00064	.058
C14V	.338	.00037	.0909
C15A	-.039	-.00003	.913
C15V	.185	.00013	.446
C17V	-.306	-.00017	.215
C18V	.045	.00003	.830
D2 V	.269	.00044	.225
D4 V	-.526	-.00025	.017
D5 A	.217	.00016	.330
D6 A	.204	.00007	.374
D7 A	.144	.00012	.463
E2 A	.329	.00092	.523
E2 C	.861	.00054	.138
E3 A	-.196	-.00024	.803
E3 C	.112	.00005	.831
E5 A	-.157	-.00004	.643

TABLE 5-19

TITLE: R2 vs. Time Waiting Parts

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	-.312	-.001	.208
A1 V	.151	.00053	.699
A3 A	.151	.00020	.442
A4 A	-.317	.00023	.186
A4 C	.346	.00002	.654
A4 V	.320	.00015	.536
A5 A	.201	.00033	.472
A5 V	-.001	-.287E-05	.997
A6 C	.039	.00003	.941
A6 V	.221	.00005	.311
A7 C	-.752	-.009	.084
A7 V	-.010	-.634E-05	.962
A9 A	.158	.00052	.532
A9 V	-.816	-.00038	.002
A11A	.026	.00001	.918
A11V	-.434	-.00016	.182
A13A	.060	.00005	.838
A13V	-.175	-.00007	.501
B1 A	.340	.00036	.337
B1 V	-.246	-.00011	.258
B2 V	-.271	-.00027	.172
B3 A	-.316	-.00024	.251
B3 V	.225	.00024	.439
B4 V	-.159	-.00004	.428
B6 C	.539	.00096	.270
B6 V	-.208	-.00019	.340
B7 A	.212	.00020	.467
B7 V	.304	.00018	.220
C1 A	-.458	-.003	.254
C3 A	.018	.00004	.949
C3 C	.088	.00010	.912
C3 V	-.052	-.00002	.887
C4 V	-.580	-.00062	.012
C5 V	.306	.00021	.389
C6 A	-.759	-.003	.003
C6 C	-.518	-.00032	.371
C8 A	-.341	-.00096	.254
C8 V	-.639	-.001	.008
C9 A	-.300	-.00018	.213
C9 V	.607	.00055	.111
C12A	-.252	-.00026	.188

TABLE 5-19 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C13A	.175	.004	.518
C13V	.459	.00049	.155
C14V	.158	.00015	.440
C15A	.104	.00013	.775
C15V	-.218	-.00014	.370
C17V	-.392	.00038	.108
C18V	-.599	-.00042	.002
D2 V	.063	.00011	.779
D4 V	-.623	-.00041	.003
D5 A	.139	.00013	.538
D6 A	.126	.00008	.586
D7 A	.278	.00032	.152
E2 A	.271	.00011	.604
E2 C	.350	.00029	.650
E3 A	.932	.00026	.068
E3 C	.015	.00001	.978
E5 A	-.094	-.00002	.783

- Direction of Correlation - Slope of Regression Line - Three of the four coefficients mentioned have negative slopes and 26 of the total of 58 have negative slopes.

- Significance of Slope - Of the four data sets with high correlation coefficients three (all with negative slopes) have significance levels less than 0.05.

5.2.3.4 Conclusions

There is no absolute linear relationship between readiness and Time Awaiting Parts as defined by the criteria used in this analysis; however, a slight trend towards an inversely proportioned relationship is evident.

5.2.4 Analysis of Readiness Versus Supply Downtime

5.2.4.1 Scatter Diagrams Run to Test the Sensitivity of Readiness and Supply Downtime

Two sets of scatter diagrams and accompanying statistics were developed to analyze the relationship between readiness, as defined by R_1 and R_2, and supply downtime. The runs were:

- R_1 versus Supply Downtime

- R_2 versus Supply Downtime

Supply downtime is the number of hours spent by fleet units waiting for parts required to correct a system degrading casualty. The amount of supply down time for each unit and for each reporting period was derived from the CASREP reports (see Section 4.1.2). The values of supply downtime depicted in the scatter diagrams range from 0-3000 hours (X-axis). The definitions of R_1 and R_2 and the data sources used to calculate these values are discussed in Section 2.3. The range of values displayed in the scatter diagrams are from 0-1 for the readiness measures (X-axis).

5.2.4.2 Observations - R_1 Versus Supply Downtime

- Visual Trends - A visual analysis suggests a strong tendency toward a pattern closely distributed about a negatively sloped line with an intercept near 1.0 on the readiness axis. There are some spurious data points with supply downtime of zero and with readiness values in the low to mid ranges. (See Appendices B-33 through B-26 for typical examples of the scatter diagrams in this run.)

- Strength of Variate Correlation - Table 5-20 lists the regression and each correlation measures associated with each data set. Eighteen of the 61 data sets have correlation coefficients with absolute values greater than 0.70.

- Direction of Correlation - Slope of Regression Line - Each one of the eighteen data sets noted above has a negative slope associated with it, and, overall, 51 of 60 sets have a negative

TABLE 5-20

TITLE: R1 vs. Supply Downtime

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	.353	.00002	.0322
A1 V	.058	.00002	.881
A3 A	-.550	-.00024	.002
A4 A	-.530	-.00018	.019
A4 V	-.908	-.00069	.012
A5 A	-.644	-.00032	.009
A5 V	-.432	-.00031	.140
A6 C	-.313	-.00013	.544
A6 V	-.018	-.00003	.934
A7 C	-.639	-.00019	.171
A7 V	-.316	-.00036	.141
A9 A	-.270	-.00027	.277
A9 V	-.540	-.00034	.086
A11A	-.829	-.00034	.00002
A11V	-.933	-.00029	.00003
A13A	-.147	-.0012	.614
A13V	-.231	-.00017	.371
B1 A	-.678	-.00026	.030
B1 V	-.139	-.00009	.526
B2 V	-.699	-.00031	.00005
B3 A	-.655	-.00055	.0079
B3 V	.132	.00021	.651
B4 V	-.687	-.00035	.00005
B6 C	-.998	-.00041	.00001
B6 V	-.105	-.00013	.633
B7 A	-.437	-.00029	.117
B7 V	-.810	-.00034	.00005
C1 A	-.753	-.0009	.030
C3 A	-.772	-.00034	.00074
C3 C	-.999	-.00044	.00008
C3 V	.236	.00015	.511
C4 A	-.965	-.00027	.00001
C4 V	.076	.00005	.762
C5 A	-.641	-.00058	.005
C5 V	.133	.00019	.714
C6 A	-.520	-.00023	.068
C6 C	-.488	-.00037	.404
C8 A	-.768	-.00035	.002
C8 V	-.101	-.00006	.707
C9 A	-.455	-.0021	.049
C9 V	-.850	-.00032	.007

TABLE 5-20 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C12A	-.544	-.00025	.0022
C13A	-.395	-.00036	.129
C13V	-.348	-.00012	.293
C14V	-.209	-.00011	.303
C15A	-.803	-.00018	.005
C15V	.381	.00022	.106
C17V	-.490	-.00014	.038
C18C	.422	.00033	.577
C18V	-.274	-.00013	.184
D2 V	.269	-.00018	.225
D4 V	-.792	-.00031	.00003
D5 A	-.561	-.00023	.006
D6 A	-.736	-.00023	.00014
D7 A	-.527	-.00027	.0039
E2 A	.020	.00009	.969
E2 C	-.720	-.00028	.279
E3 A	-.761	-.00039	.238
E3 C	-.867	-.00021	.025
E5 A	-.985	-.0004	.00001

slope, strongly suggesting a trend of decreased readiness with increased supply downtime.

- Significance of Slope - Sixteen of the eighteen values mentioned above have significant slopes (they have significance values less than the criteria, 0.05.)

5.2.4.3 Observations - R_2 Versus Supply Downtime

- Visual Trends - A visual inspection reveals that there is more of the tendency toward the negatively sloped pattern observed in Section 5.2.4.1. See Appendices B-37 through B-40 for typical examples.

- Strength of Variate Correlation - Table 5-21 lists the correlation and regression measures associated with each data set. Forty-five of the 60 sets have correlation coefficients with absolute values greater than 0.70.

- Direction of Correlation - Slope of Regression Line - Each of the 60 data sets has a negative slope.

- Significance of Slope - Of the 45 data sets mentioned previously, 42 have significance values less than 0.05.

5.2.4.4 Conclusions

There is a linear relationship between supply down time and readiness as defined by R_2. Seventy-five percent of the data sets have high correlations and all of the data sets exhibit a negative slope. Furthermore, over 90% of the slopes of those sets that exhibit high correlation are significant.

Statistically, the conclusion is that R_2 will decrease as supply downtime increases. The linear relationship between R_1 and supply downtime is not as strong, only 30% of the data sets exhibit high correlation, but the slope is negative and significantly different than zero.

5.2.5 Analysis of Readiness Versus Maintenance Downtime

5.2.5.1 Scatter Diagrams Run to Test the Sensitivity of Readiness and Supply Downtime

Two sets of scatter diagrams and accompanying statistics were developed to analyze the relationship between readiness, as defined by R_1 and R_2, and maintenance downtime. The runs were:

- R_1 versus Maintenance Downtime

- R_2 versus Maintenance Downtime.

Maintenance downtime is the number of hours spent by fleet technicians performing active maintenance actions to correct a system degrading casualty. The amount of maintenance downtime for each unit for each reporting period was derived from the CASREP reports (See Section 4.1.2). The values of maintenance downtime depicted in the scatter diagrams range

TABLE 5-21

TITLE: R2 vs. Supply Downtime

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	-.483	-.00025	.042
A1 V	-.810	-.00031	.008
A3 A	-.537	-.00037	.003
A4 A	-.896	-.00037	.00001
A4 V	-.809	-.00061	.051
A5 A	-.610	-.00045	.016
A5 V	-.735	-.00057	.004
A6 C	-.843	-.00039	.035
A6 V	-.791	-.00045	.00001
A7 C	-.802	-.00037	.055
A7 V	-.728	-.00057	.00008
A9 A	-.605	-.00043	.008
A9 V	-.897	-.00032	.00018
A11A	-.939	-.00058	.00001
A11V	-.936	-.00029	.00002
A13A	.133	.00132	.651
A13V	-.912	-.00049	.00001
B1 A	-.886	-.00038	.00064
B1 V	-.903	-.00037	.00001
B2 V	-.965	-.00049	.00001
B3 A	-.527	-.00053	.043
B3 V	-.055	-.00006	.853
B4 V	-.737	-.00044	.00001
B6 C	-.998	-.00048	.00001
B6 V	-.794	-.00043	.00001
B7 A	-.362	-.00030	.204
B7 V	-.856	-.00052	.00001
C1 A	-.671	-.00042	.069
C3 A	-.869	-.00055	.00003
C3 C	-.999	-.00046	.00001
C3 V	-.956	-.00044	.00002
C4 A	-.974	-.00043	.00001
C4 V	-.745	-.00030	.00039
C5 A	-.652	-.00059	.005
C5 V	-.674	-.00060	.033
C6 A	-.954	-.00040	.00001
C6 C	-.999	-.00054	.00003
C8 A	-.708	-.00049	.00674
C8 V	-.911	-.00042	.00001
C9 A	-.931	-.00043	.00001
C9 V	-.832	-.00043	.010

TABLE 5-21 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C12A	-.905	-.00048	.00001
C13A	-.740	-.00058	.001
C13V	-.925	-.00033	.00005
C14V	-.780	-.00036	.00001
C15A	-.852	-.00036	.002
C15V	-.327	-.00018	.172
C17V	-.461	-.00023	.054
C18C	-.751	-.00084	.249
C18V	-.767	-.00034	.00001
D2 V	-.970	-.00065	.00001
D4 V	-.817	-.00044	.00001
D5 A	-.858	-.00047	.00001
D6 A	-.866	-.00046	.00001
D7 A	-.528	-.00038	.004
E2 A	-1.000	-.00061	.0001
E2 C	-.997	-.00050	.003
E3 A	-.333	-.00004	.667
E3 C	-.854	-.00038	.031
E5 A	-.987	-.00036	.00001

from 0-3600 hours (X-axis). The definitions of R_1 and R_2 and the data sources used to calculate these values are discussed in Section 2.3. The range of values displayed in the scatter diagrams are from 0-1 for the readiness measures (X-axis).

5.2.5.2 Observations - R_1 Versus Maintenance Downtime

- Visual Trends - Inspection of the scatter diagrams for R_1 vs. Maintenance Downtime reveals that a negatively sloped pattern exists for approximately half of the diagrams. These scatter diagrams have a generally negative sloped pattern except for data points scattered near the X-axis with low readiness values. (See Appendices B-41 through B-44 for examples of this trend.)

- Strength of Variate Correlation - Table 5-22 shows the correlation coefficients, slopes, and significance values associated with the 60 scatter diagrams. Of these 60, five have correlation coefficients > .7 or < -.7.

- Direction of Correlation - Slope of Regression Line - The five scatter diagrams mentioned above all have negative slopes and, overall negative slopes are associated with 48 of the 59 scatter diagrams. This evidence suggests that a correlation exists for an inversely proportioned relationship (i.e., readiness decreases as maintenance down time increases).

- Significance of Slope - Three of the five scatter diagrams with high correlation coefficients have significance values less than 0.05.

5.2.5.3 Observations - R_2 Versus Maintenance Downtime

- Visual Trends - The scatter diagrams of R_2 vs. maintenance down time display a strong tendency toward a negatively sloped pattern. There are more scatter diagrams with this pattern than for R_1 vs. maintenance downtime. Appendices B-45 through B-48 are typical scatter diagrams from this set.

- Strength of Variate Correlation - Table 5-23 shows the correlation coefficients, slopes, and significance values associated with the scatter diagrams of this data. Seventeen of the 59 scatter diagrams have correlation coefficients (absolute value) greater than .7. This supports the conclusions of the visual observations.

- Direction of Correlation - Slope of Regression Line - Sixteen of the 17 high correlations have negative slopes and, overall, 52 of 59 have negative slopes, again strongly suggesting an inversely proportioned relationship.

- Significance of Slope - Fourteen of the 17 scatter diagrams with high correlation have significance values less than 0.05. This supports a theory of a negative sloping regression line.

TABLE 5-22

TITLE: R1 vs. Maintenance Downtime

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	-.263	-.00009	.291
A1 V	.452	.00023	.222
A3 A	-.575	-.00015	.001
A4 A	.039	.00009	.876
A4 C	-1.000	-.00046	.000
A4 V	-.541	-.00063	.268
A5 A	-.545	-.00020	.036
A5 V	-.393	-.00015	.184
A6 C	.096	.00010	.856
A6 V	.121	.00032	.582
A7 C	-.635	-.00020	.175
A7 V	-.295	-.00044	.171
A9 A	-.403	-.00033	.098
A9 V	-.818	-.00110	.002
A11A	-.307	-.00032	.215
A11V	-.145	-.00043	.671
A13A	-.825	-.00027	.00028
A13V	-.235	-.00026	.363
B1 A	-.443	-.00049	.200
B1 V	.006	.858E-5	.977
B2 V	-.176	-.00055	.379
B3 A	-.596	-.00016	.019
B3 V	-.250	-.00014	.388
B4 V	-.706	-.00040	.00003
B6 C	-.726	-.00405	.102
B6 V	-.080	-.00016	.715
B7 A	-.679	-.00042	.008
B7 V	-.436	-.00035	.071
C1 A	-.374	-.00026	.362
C3 A	-.319	-.00020	.246
C3 V	.235	.00026	.511
C4 A	-.312	-.00298	.378
C4 V	-.113	-.00013	.655
C5 A	-.655	-.00035	.003
C5 V	-.195	-.00025	.588
C6 A	-.093	-.00031	.763
C6 C	-.274	-.00014	.656
C8 A	-.698	-.00056	.007
C8 V	-.083	-.00011	.756
C9 A	-.027	-.00006	.914
C9 V	-.642	-.00054	.085

TABLE 5-22 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C12A	-.217	-.00030	.258
C13A	-.344	-.00033	.193
C13V	.168	.00044	.623
C14V	-.103	-.00009	.613
C15A	-.237	-.00019	.506
C15V	-.029	-.00002	.902
C17V	-.429	-.00018	.075
C18C	-.839	-.00261	.159
C18V	-.057	-.00003	.781
D2 V	.147	.00036	.515
D4 V	-.514	-.00021	.020
D5 A	-.159	-.00019	.476
D6 A	-.400	-.00017	.075
D7 A	-.421	-.0002	.025
E2 A	.019	.0025	.968
E2 C	.301	.0016	.699
E3 A	.406	.00012	.593
E3 C	-.670	-.00018	.146
E5 A	-.614	-.00184	.044

TABLE 5-23

TITLE: R2 vs. Maintenance Downtime

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	-.482	-.00023	.043
A1 V	.184	.00012	.635
A3 A	-.642	-.00027	.0002
A4 A	.062	.00018	.797
A4 C	-.394	-.00046	.438
A4 V	-1.000	-.00046	.000
A5 A	-.613	-.00033	.012
A5 V	-.647	-.00027	.017
A6 C	-.020	-.00003	.967
A6 V	-.630	-.00067	.001
A7 C	-.403	-.0002	.429
A7 V	-.808	-.00081	.00001
A9 A	-.759	-.00044	.0003
A9 V	-.588	-.00046	.056
A11A	-.210	-.00033	.402
A11V	-.123	-.00037	.717
A13A	-.893	-.00033	.00002
A13V	-.744	-.00059	.0006
B1 A	-.266	-.00033	.455
B1 V	-.501	-.00046	.014
B2 V	-.131	-.00047	.512
B3 A	-.742	-.00024	.001
B3 V	-.934	-.00038	.00001
B4 V	-.757	-.00051	.00001
B6 C	-.711	-.00461	.112
B6 V	-.660	-.00058	.0006
B7 A	-.789	-.00061	.0007
B7 V	-.448	-.00052	.061
C1 A	-.787	-.00029	.02
C3 A	-.227	-.0002	.414
C3 V	-.485	-.00041	.154
C4 A	-.125	-.00188	.730
C4 V	-.599	-.00041	.008
C5 A	-.730	-.00039	.0008
C5 V	-.291	-.00023	.414
C6 A	-.297	-.00094	.324
C6 C	-.976	-.00036	.004
C8 A	-.740	-.00090	.003
C8 V	-.491	-.00055	.053
C9 A	-.108	-.00024	.659
C9 V	-.373	-.00044	.361

TABLE 5-23 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C12A	-.370	-.00058	.048
C13A	-.863	-.0007	.00002
C13V	.064	.00017	.850
C14V	-.576	-.00041	.002
C15A	-.099	-.00015	.784
C15V	-.781	-.00048	.00008
C17V	-.549	.0004	.018
C18C	.944	.00418	.055
C18V	-.569	-.00031	.002
D2 V	.044	.00011	.844
D4 V	-.576	-.00034	.007
D5 A	-.150	-.00024	.503
D6 A	-.295	-.00022	.193
D7 A	-.534	-.00035	.003
E2 A	-1.000	-.01750	.000
E2 C	.844	.00594	.155
E3 A	.492	.00003	.507
E3 C	-.562	-.00029	.244
E5 A	-.544	-.00146	.083

5.2.5.4 Conclusions

There is some linear relationship between maintenance downtime and R_2. About 30% of the data sets have high correlation coefficients, most of these being negative, and have slopes significantly distinguishable from zero. This would support the conclusion that readiness decreases with increased maintenance downtime.

5.2.6 Analysis of Readiness Versus Radar Operating Time

5.2.6.1 Scatter Diagrams Run to Test the Sensitivity of Readiness and Radar Operating Time

Four sets of scatter diagrams were developed to examine the relationship between readiness and radar operating time. The four runs are:

- R_1 versus Actual Radar Operating Time
- R_2 versus Actual Radar Operating Time
- R_1 versus Estimated Radar Operating Time
- R_2 versus Estimated Radar Operating Time.

Two sets of radar operating times were used in this analysis. The actual values of radar operating time were derived from the ITT/Gilfillan reports as explained in Section 4.1.9. The estimated values were calculated for periods during which the data was unavailable in the ITT/Gilfillan reports, which had significant gaps in data reporting.

In order to calculate the estimated radar operating time, a multiplier was defined using actual ship operating time and actual radar operating time, as reported in the ITT/Gilfillan reports. A mean ratio was established using the known quantities, then used as a multiplier with actual ship operating time to obtain an estimate of the unreported radar operating time values.

5.2.6.2 Observations - R_1 Versus Actual Radar Operating Time

- Visual Trends - Visual analysis reveals that there is not a discernable pattern present in the data set. The majority of the diagrams show random scatterings. See Appendices B-49 through B-52 for typical diagrams of this data set.
- Strength of Variable Correlation - Table 5-24 gives the correlation coefficient, slopes, and significance values associated with each scatter diagram. There are only two scatter diagrams with associated correlation coefficients (absolute value) greater than 0.7.
- Direction of Correlation - Slope of Regression Line - The two coefficients mentioned above are both positive and 34 of the 53 scatter diagrams have positive slopes.

TABLE 5-24

TITLE: R1 vs. Radar Operational Time

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	.117	.013	.665
A3 A	.100	.00002	.711
A4 A	.497	.00015	.035
A4 C	-.583	-.00004	.416
A5 A	.260	.00008	.413
A5 V	-.221	-.00010	.778
A6 C	.684	.00019	.202
A6 V	.582	.00012	.047
A7 C	-.284	-.00014	.584
A7 V	.561	.00022	.072
A9 A	-.228	-.00007	.376
A9 V	.368	.00011	.369
A11A	.111	.00004	.682
A13A	.292	.0002	.310
A13V	.659	.00021	.153
B1 A	.581	.00021	.077
B1 V	-.065	-.00003	.866
B2 V	.207	.00018	.457
B3 A	-.178	-.00005	.524
B3 V	.670	.00036	.068
B4 V	-.596	-.00006	.008
B6 C	.144	.00004	.784
B6 V	-.231	-.00004	.426
B7 A	.441	.00017	.114
C1 A	.162	.00006	.701
C3 A	.758	.0004	.002
C3 C	-.082	-.00006	.917
C4 A	.002	.859	.994
C4 V	.304	.00013	.507
C5 A	.335	.00008	.240
C5 V	.388	.0001	.611
C6 A	.304	.00013	.362
C6 C	.228	.00005	.712
C8 A	.398	.00012	.177
C8 V	-.520	-.00014	.289
C9 A	-.030	-.00001	.904
C9 V	.081	.00004	.918
C12A	-.286	-.00015	.341
C13A	.413	.00017	.234
C13V	-.630	-.00015	.369
C14V	-.159	-.00005	.587

TABLE 5-24 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C15A	-.299	-.00006	.401
C15V	.529	.00011	.115
C17V	.438	.00017	.324
C18V	-.111	-.00003	.670
D2 V	.237	.00017	.608
D4 V	-.431	-.00019	.246
D5 A	-.060	-.00002	.804
D6 A	.228	.00006	.346
D7 A	.480	.00013	.023
E2 C	.863	.00047	.136
E3 C	.375	.00018	.533
E5 A	-.147	-.00003	.685

5.2.6.3 Observations - R_2 Versus Actual Radar Operating Time

- Visual Trends - A visual appraisal of the scatter diagrams reveals that there is no common pattern among them. Appendices B-53 through B-55 are representative of the scatter diagrams from this set.

- Strength of Variate Correlation - Table 5-25 lists the correlation coefficients, slopes, and significance values associated with each scatter diagram. Only three of the diagrams have correlation coefficients with an absolute value greater than 0.7.

- Direction of Correlation - Slope of Regression Line - Thirty of the regressions have negative slopes and 22 have positive slopes. Of the scatter diagrams with high correlation two have negative slopes and one has a positive slope.

- Significance of Slope - Scatter diagram B4V (R = -.75) has a significance value less than 0.05.

5.2.6.4 Observations - R_1 Versus Estimated Radar Operating Time

- Visual Trends - A visual inspection of the scatter diagrams reveals no definite patterns in the data. See Appendices B-56 through B-59 for typical scatter diagrams in this run.

- Strength of Variate Correlation - Table 5-26 lists the correlation coefficients, slopes, and significance values associated with each scatter diagram. Four of the 60 data sets have correlation coefficients greater than 0.7.

- Direction of Correlation - Slope of Regression Line - These four correlation coefficients are all positive and 43 of the 60 diagrams in this run are positive.

- Significance of Slope - Two of the four data sets with high correlation coefficients have significance values less than 0.05.

5.2.6.5 Observations - R_2 Versus Estimated Radar Operating Time

- Visual Trends - Visual analysis shows no discernable pattern in the scatter diagrams. See Appendices B-60 through B-62 for typical scatter diagrams of this set.

- Strength of Variate Correlation - Table 5-27 lists the correlation and regression measures associated with the scatter diagrams of this set. Only three of the 60 data sets have correlation coefficients with absolute values greater than 0.7.

- Direction of Correlation - Slope of Regression Line - All three of the data sets with high correlation coefficients are negative and 29 of the 60 scatter diagrams have negative slopes associated with them.

TABLE 5-25

TITLE: R2 vs. Radar Operational Time

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	-.190	-.00008	.479
A3 A	-.207	-.00009	.440
A4 A	.754	.00011	.308
A4 C	-.583	-.00004	.417
A5 A	.229	.00011	.472
A5 V	-.221	-.00011	.778
A6 C	-.521	-.00018	.367
A6 V	-.126	-.00002	.695
A7 C	-.197	-.00015	.707
A7 V	.562	.00024	.071
A9 A	-.229	-.00008	.375
A9 V	-.127	-.00002	.763
A11A	-.014	-.715E-05	.957
A13A	.133	.00011	.648
A13V	.240	.00009	.645
B1 A	.414	.00017	.234
B1 V	-.354	-.00021	.349
B2 V	.037	.00004	.894
B3 A	-.303	-.00011	.270
B3 V	.125	.00004	.767
B4 V	-.750	-.00010	.00033
B6 C	.198	.00006	.705
B6 V	-.300	-.00005	.296
B7 A	.424	.00020	.130
C1 A	-.337	-.00006	.413
C3 A	.391	.00030	.186
C3 C	-.074	-.00006	.925
C4 A	.042	.00002	.908
C4 V	.059	.00002	.898
C5 V	.190	.00003	.809
C6 A	-.012	-.684E-05	.970
C6 C	-.719	-.00012	.170
C8 A	.420	.00019	.152
C8 V	-.613	-.00013	.195
C9 A	-.195	-.00010	.437
C9 V	-.226	-.00012	.773
C12A	-.314	-.00025	.295
C13A	.350	.00017	.320
C13V	-.540	-.00015	.459
C14V	-.217	-.00011	.455
C15A	-.350	-.00012	.320

TABLE 5-25 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C15V	.272	.00011	.445
C17V	-.223	-.00011	.630
C18V	-.565	-.00022	.017
D2 V	.145	.00021	.756
D4 V	-.568	-.00027	.1102
D5 A	.218	.00009	.369
D6 A	-.237	-.00016	.327
D7 A	.233	.00008	.295
E2 C	.384	.00027	.615
E3 C	.270	.00027	.659
E5 A	-.098	-.00002	.785

TABLE 5-26

TITLE: R1 vs. Operational Time

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
A1 A	.117	.00003	.665
A1 V	.489	.00010	.218
A3 A.	.157	.00007	.422
A4 A	.497	.00015	.035
A4 C	-.583	-.00004	.416
A4 V	-.013	-.448	.979
A5 A	.163	.00006	.561
A5 V	-.173	-.00008	.590
A6 C.	.684	.00019	.202
A6 V	.303	.00007	.206
A7 C	-.284	-.00014	.584
A7 V	.607	.00022	.0044
A9 A	-.228	-.00007	.376
A9 V	.228	.0007	.499
A11A	.065	.00002	.797
A11V	.611	.00028	.045
A13A	.292	.00020	.310
A13V	.417	.00020	.137
B1 A	.581	.00021	.077
B1 V	.072	.00003	.776
B2 V	.433	.00024	.026
B3 A	-.178	-.00005	.524
B3 V	.359	.00019	.307
B4 V	-.414	-.00006	.028
B6 C	.144	.00004	.784
B6 V	.086	.00002	.725
B7 A	.441	.0017	.114
B7 V	.443	.00024	.065
C1 A	.162	.00006	.701
C3 A	.714	.00042	.002
C3 C	-.082	-.00006	.917
C3 V	-.275	-.00008	.549
C4 A	.0027	.859	.994
C4 V	.136	.00005	.655
C5 A	.321	.00008	.208
C5 V	.478	.00014	.229
C6 A	.223	.00009	.484
C6 C	.228	.00005	.712
C8 A	.398	.00012	.177
C8 V	-.420	-.00017	.173
C9 A	-.030	-.00001	.904

TABLE 5-26 Cont.

RADAR	CORRELATION (COEF.)	SLOPE	SIGNIFICANCE
C9 V	.392	.00017	.336
C12A	.014	.670	.942
C13A	.324	.00014	.258
C13V	.390	.00012	.264
C14V	-.244	-.00008	.273
C15A	-.299	-.00006	.401
C15V	.372	.00007	.170
C17V	.328	.00017	.182
C18C	.968	.00023	.031
C18V	-.193	-.00006	.401
D2 V	.351	.00015	.139
D4 V	-.344	-.00016	.136
D5 A	.269	.00007	.269
D6 A	.091	.00004	.694
D7 A	.453	.00014	.015
E2 A	.071	.401	.909
E2 C	.863	.00047	.136
E3 A	.912	.00020	.268
E3 C	-.026	-.00001	.960
E5 A	-.093	-.00002	.784

TABLE 5-27

TITLE: R2 vs. Operational Time

RADAR	CORRELATION (R)	SLOPE	SIGNIFICANCE (R)
A1 A	-.190	-.00008	.479
A1 V	.239	.00011	.567
A3 A	-.003	-.210	.987
A4 A	.254	.00011	.308
A4 C	.583	.00004	.416
A4 V	.112	.00004	.831
A5 A	.156	.00008	.577
A5 V	-.146	-.00010	.649
A6 C	-.521	-.00018	.367
A6 V	-.186	-.00004	.443
A7 C	-.197	-.00015	.707
A7 V	.625	.00026	.00316
A9 A	-.229	-.00008	.375
A9 V	-.206	-.00004	.542
A11A	-.051	-.00003	.840
A11V	.598	.00028	.051
A13A	.133	.00011	.648
A13V	.231	.00011	.426
B1 A	.414	.00017	.234
B1 V	-.206	-.00012	.411
B2 V	.309	.00022	.124
B3 A	-.303	-.00011	.270
B3 V	-.200	-.00010	.578
B4 V	-.566	-.00009	.0016
B6 C	.198	.00006	.705
B6 V	.053	.00001	.827
B7 A	.424	.0002	.130
B7 V	.270	.00021	.00019
C1 A	-.337	-.00006	.413
C3 A	.389	.00032	.150
C3 C	-.074	-.00012	.925
C3 V	-.280	-.00006	.542
C4 A	.042	.00002	.908
C4 V	-.157	-.00005	.606
C5 A	.203	.00005	.433
C5 V	.430	.00012	.286
C6 A	-.068	-.00004	.832
C6 C	-.719	-.00012	.170
C8 A	.420	.00019	.152
C8 V	-.372	-.00021	.232
C9 A	-.195	-.00010	.437

TABLE 5-27 Cont.

RADAR	CORRELATION (R)	SLOPE	SIGNIFICANCE (R)
C9 V	.295	.00018	.477
C12A	-.0031	-.221	.987
C13A	.265	.00014	.359
C13V	.244	.00011	.496
C14V	-.274	-.00012	.215
C15A	-.350	-.00012	.320
C15V	.100	.00004	.722
C17V	.093	.00009	.711
C18C	-.874	-.00029	.125
C18V	-.550	-.00024	.009
D2 V	.337	.00026	.158
D4 V	.336	.00021	.145
D5 A	.244	.00011	.286
D6 A	.253	.00018	.266
D7 A	.279	.00012	.149
E2 A	.017	.319	.909
E2 C	.384	.00027	.615
E3 A	-.982	-.00007	.117
E3 C	-.014	-.00001	.977
E5 A	-.065	-.00001	.848

- Significance of Slope - None of the data sets with high correlation coefficients have significance levels less than 0.05.

5.2.6.6 Conclusions

There is no linear relationship between readiness and radar operating time using the criteria of this analysis. Less than 10% of the data sets exhibit high correlation and no negative or positive slope trend is perceivable.

5.3 Overall Findings

5.3.1 General Observations

As previously iterated in Sections 5.1 and 5.2, there were few observable trends or correlations in the various analyses undertaken in the study. (See Table 5-27.) No trends or significant correlations existed when both readiness measures were compared to organizational man-hour and organizational parts expenditures. The specific results of these program runs are detailed in Sections 5.1.1., 5.1.2., 5.2.1, 5.2.2, and 5.2.6. Readiness indicators were plotted versus calendar time, ship operating intensity, and radar operating time. Observable trends are indicated when the readiness measures were plotted versus depot man-hour and parts expenditures, maintenance personnel availability, time spent awaiting parts, and supply and maintenance downtime.

5.3.2 Observable Trends

When the two readiness indicators used in the study were compared to depot resource expenditures (man-hours and parts), both R_1 and R_2 showed marked decreases in the reporting period immediately following a large depot-level resource expenditures. Readiness generally improved in the following reporting periods. Specific examples and probable reasons for this phenomena are detailed in Section 5.1.3.

Another area examined which produced observable trends in changes of system readiness when compared to resource expenditures way that of readiness versus maintenance personnel availability. As detailed in Section 5.1.4, a slight trend towards increased readiness with increased personnel availability exists. A third area with observable trends is that of readiness versus the various factors contributing to actual system downtime (i.e., time awaiting parts, supply downtime, and maintenance downtime). When readiness is plotted versus all of these indicators, an inverse correlation exists to some degree. (See Table 5-28 and Sections 5.2.3, 5.2.4, and 5.2.5.) The results are those that logically can be expected; however, the trends and correlations observed do not support a statistically significant enough case to quantitatively tie readiness to resource expenditures.

6.0 ECONOMIC ANALYSIS OF THE SENSITIVITY OF OPERATIONAL READINESS TO RESOURCE EXPENDITURES

As discussed in Section 1.0 of this report, the problem of relating variable levels of support resources (manpower, parts, dollars, etc.) to operational readiness has been approached in many ways. The specific objective of this study was to pursue, in a comprehensive fashion, all reasonable approaches to demonstrating a statistical relationship between resources and readiness. As is indicated in Section 5.0, very little statistical evidence was found to support the intuitively logical hypothesis that increasing maintenance resources results in improved operational readiness; or stated conversely, that decreasing support resources precipitates a decline in operational readiness. Notwithstanding the lack of statistical evidence to support this hypothesis, it is difficult to reject a concept which is so simple and logical. For this reason it was decided late within this effort to conceptualize a wholly different (i.e., non-statistically based) approach to the resource/readiness problem. The remainder of Section 6.0 documents our initial thoughts on an economic approach to the resource/readiness problem. Time did not permit the complete development of this approach, but the concept is logical and its application so appropriate that with reasonable data this methodology may capture the underlying relationship between resources and readiness.

The basis of this approach is in establishing the impact of resources on operational readiness by varying the resources expended while holding the base period readiness level constant. By associating the change in readiness measures between the two periods (base and succeeding period) as a function of the total resources expended, it is hypothesized that the magnitude change in readiness will quantitatively relate to the resources consumed. By plotting numerous pairs of readiness measures and resource expenditures for different constant base period readiness levels, a set of lines or curves can be developed which relate probable readiness levels achievable from infusion of various levels of resources. (The confidence limits associated with this estimated readiness level are determined by the scatter of the input data about the fitted curve.) A fictitious quantitative example should help to illustrate the mechanics of this approach.

Assume that historical readiness and resource data are available quarterly for system XYZ over a period of time, say 5 years. In order to increase the probability of constructing fitting readiness return curves, the data is partitioned into sets reflecting their past operational readiness levels. For instance, the data may be grouped into four sets as follows:[1]

Set	Demonstrated Readiness Level (Range)
I	0.0 - 0.25
II	0.26 - 0.50
III	0.51 - 0.75
IV	0.76 - 1.00

---

[1] Partitioning of the data into homogeneous readiness sets will help to graphically illustrate the impact that the state of current readiness has on the future state of readiness.

(The number of sets and ranges within each set should be determined after reviewing the quantity and distribution of the readiness data. Ideally the ranges should be established as small as possible to encourage minimum data scatter about the readiness return curves.) Each set of data will then be used to construct individual readiness return curves by plotting the historic change in readiness from one period to the next, and the associated expenditure of resources during this time period. Figure 6-1 is an example of the data plot and type of fitted curve which theoretically could result from this approach.

Equipped with a readiness return curve for each set of base period readiness levels, and an indication of the current readiness of the system, an analyst can infer the probable levels of readiness which would result from various levels of resource expenditures. For multi-period planning purposes this algorithm can be interatively applied and dynamic optimization techniques can be employed to optimize readiness levels under varying resource constraints.

This approach to the resource/readiness problem differs significantly from prior efforts in several ways:

- It is based on the marginal return of varying resource expenditures at fixed levels of readiness, i.e., the readiness achieveable in future periods is a function of both the resources applied and the current readiness level of the system

- It can logically explain (and predict) decreases in system readiness in the presence of significant resource expenditures (notice the change in readiness resulting from an investment of less than $50,000 in Figure 6-1).

- It is well-suited to multi-period resource planning, automation, and resource optimization.

- The methodology and algorithm are easily comprehensible and reducible to graphical formats for presentation purposes.

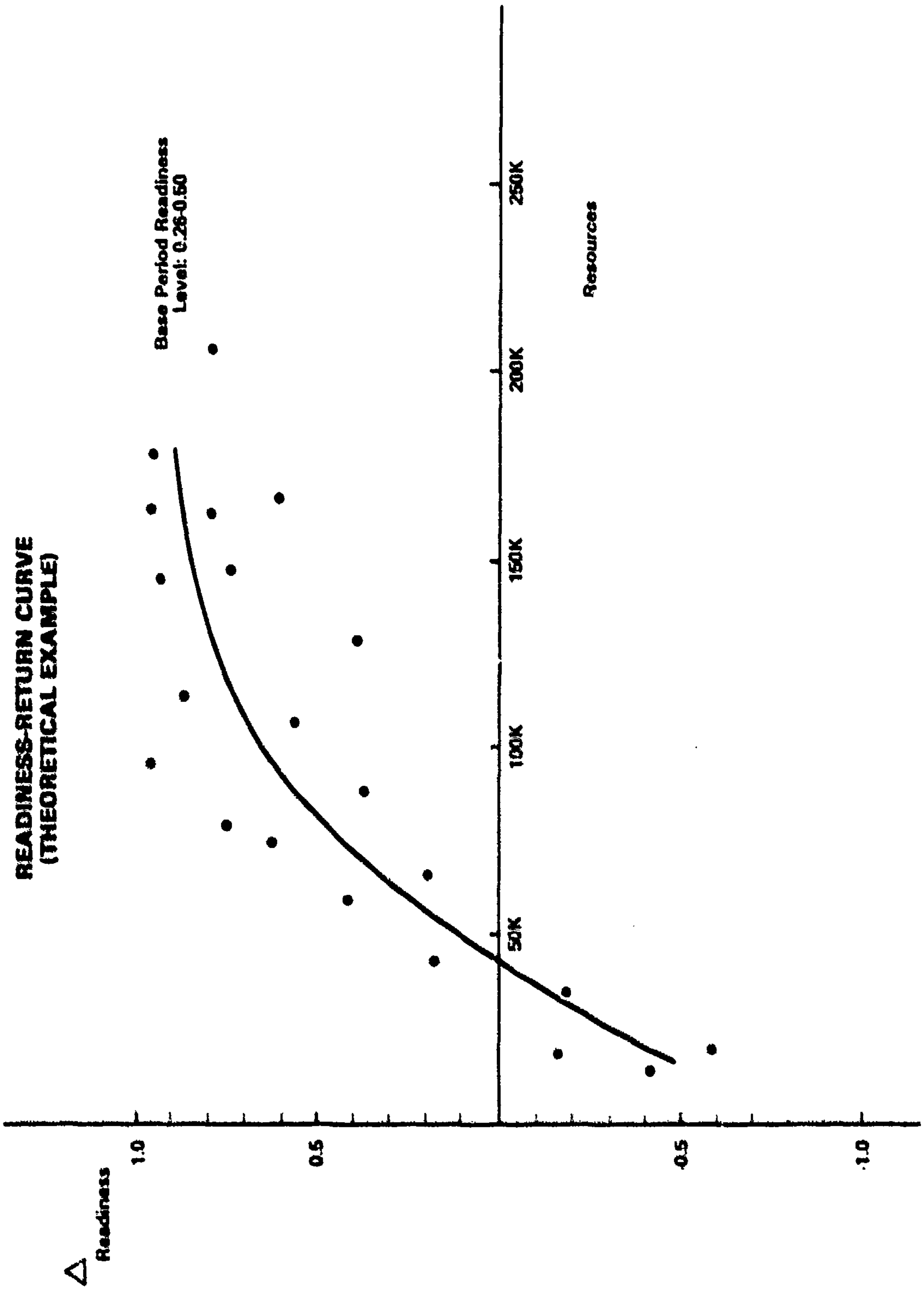
READINESS-RETURN CURVE
(THEORETICAL EXAMPLE)
Base Period Readiness
Level: 0.26-0.50
Resources
50K
100K
150K
200K
250K
Δ Readiness
1.0
0.5
-0.5
-1.0

Figure 6-1

7.0 CONCLUSIONS AND RECOMMENDATIONS

The primary objective of this study was to establish and demonstrate the existence of statistical relationships between operational readiness and those resources expended to maintain operational readiness. In pursuit of this objective, two measures of operational readiness were examined: 1) R_1, which considered the radar system to be available (operable) only when it was actually operating (this is the traditional approach to operational availability A_o), and 2) R_2, which considered the radar system to be available at all times, except when it was known to be inoperable. With very few exceptions, it was nearly impossible to statistically relate either readiness measure with any of the resource factors considered. One of the exceptions to this condition was observed in the correlation between supply downtime and operational readiness. This is not a particularly significant discovery in light of the fact that supply downtime is a major determinant of total downtime, and total downtime is an explicit parameter in the formulaes of both R_1 and R_2, as shown below:

$$R_1 = \frac{\text{operating time}}{\text{operating time + downtime}}$$

$$R_2 = \frac{\text{calendar time - downtime}}{\text{calendar time}}$$

(downtime = maintenance downtime + supply downtime)

The fact that readiness varies with changes in supply downtime is more of a statement of the relationship between parameters in an equation, than the discovery of a genuine cause and effect relationship. Frequently, this apparent correlation is interpreted as the primary mechanism through which readiness can be affected, i.e., "improved." It is our opinion that this conclusion, although not without merit, is distinctively short-sighted for the following reasons:

- Low operational readiness usually results from low system reliability; for example, the AN/SPS-48A radar system has demonstrated MTBF of 54 hours. Regardless of the extent or depth of repair parts available, it is practically impossible to maintain the AN/SPS-48A in a fully operational condition for an extended period of time.

- Supply downtime is a function of two conditions: parts availability and supply system procedures. Increasing spare levels increases parts availability. But, during a routine deployment it is probable that a system with a very low reliability will exhaust organizational level spares and, therefore, accumulate downtime as a function of the operation of the supply system.

- The life cycle cost of maintaining operational readiness via extensive and intensive supply support is seldom a cost effective solution.

For existing systems, exhibiting low levels of operational readiness, resource emphasis on supply support may be the only feasible mechanism through which to improve near-term operational readiness. This approach must be recognized as a stop-gap measure, it is not a long-term solution to the problem. The only mechanism through which operational readiness can be permanently and significantly improved is through improved system reliability. Supply downtime affects operational readiness only after an equipment failure. Therefore, emphasis should be placed on avoiding equipment failure rather than improving supply support.

An unreliable system whose operating status is continually supported by an extensive and expensive supply support system will quickly accrue operational costs which may warrant equipment redesign. It is therefore recommended that life cycle cost analyses and trade-off analyses be conducted before expensive resources are allocated to perpetuate the life of unreliable systems under the guise of improving its readiness.

Nothwithstanding the numerous shortfalls in the data discussed in Section 4.0, there may be analytical approaches to structuring existing data for analysis which will minimize the effect of "bad" data. For instance, it is recommended that future studies establish scaled equipment performance levels of readiness. That is, recognize degraded levels of performance, rather than using the dichotometric (up or down) approach to readiness. Taking this approach will be more difficult during the data assembly portion of the study in that each equipment failure will have to be individually evaluated. The approach will, however, accomplish several desirable goals. First, since there is no standardized guidance for determining the degree of degradation on specific system failures, a C-2 CASREP on one ship may be a C-3 CASREP on another, for the same type of failure, separate evaluation of failures would standardize degradation levels, thus producing a uniform readi- ness data base for analysis. A second advantage would be to conform to the JCS definition of readiness. ("The degree to which the organization is capable of performing the missions for which it was organized or designed.")

It is also recommended that future studies examine the feasibility of event-based analysis, vice the continuous period analysis pursued by a majority of the resource/readiness studies conducted in the past. By studying the resource/readiness relationship at the time of an event (system failure), causes may be observable which were previously masked by averaging resoure/readiness measures over an arbitrary period of time. Event-based analysis would attempt to categorize the specific cause of failures, and thus, when a readiness-resource relationship was pursued, individual resource quantities versus readiness would not be obscured by data generated from totally unrelated causes.

A simple example illustrating this point would be a resources to readiness study of a family car, a simple system for which all resource expenditures and levels of readiness could be carefully tracked and categorized. If, for example, corrective maintenance man-hours (as a resource) were plotted against readiness, one would expect that readiness over time would be inversely proportional to man-hours expended. In such a plot, low levels of readiness not correctable by maintenance man-hour expenditures would distort the expected inverse relationship between readiness and corrective maintenance man-hours. Defective or unavailable spare parts, faulty maintenance documentation, downtime attributed to time spent performing preventive maintenance, and other circumstances would generate data points that do not fit into the graphed line illustrating the inverse relationship. Analysis of the data would, therefore, not yield a clear correlation, even in this simple system. Event-based analysis, on the other hand, where readiness and only those failures resulting in the expenditure of corrective maintenance man-hours were plotted, chances of a correlation would be more likely.

Various forms of statistical analysis have been attempted in this study, and in many more ambitious efforts which preceded it. To date, the results of this form of analysis have been rather dismal. Future pursuit of this specific form of analysis, without significant modification, is not recommended. Alternative analytical methods, such as the economic analysis discussed in Section 6.0, or further exploration of reliability's impact on readiness offer more potential for success in solving the resource/readiness problem than continued pursuit of an "appropriate statistical procedure." It is recommended that future studies be encouraged to experiment with such alternative methodologies.

7.1 Specific Recommendation on Data Sources

7.1.1 FORSTAT Reports

It is understood that the FORSTAT system operates as a strategic system used to track fleet status. Some thought should be given to its usefulness in analyzing the readiness-resource problem. A greater volume of data should be saved from FORSTATs submitted by the fleet if this problem is to be accommodated. The narrative portions of the reports would be very useful in establishing precise conditions at any point in time. Errors in the existing data base (130 days underway in a 90-day quarter) are very perplexing.

7.1.2 AN/SPS-48 Shipboard Reliability Support Program Quarterly Reports

As previously noted, system downtime in these reports reflects only the time it takes to repair the radar. It appears that the Navy and ITT/Gilfillan would be better served if total downtime were also collected in these reports. It has been clearly established by several sources that the time to repair the radar is quite low. It is logical to estalish the other factors contributing to low readiness over time. Reductions in the delays experienced due to the supply system, due to administrative delay, or due to other factors are strategically vital and directly related to the anti-air warfare posture of each ship. These reports could be modified to help serve this purpose.

7.1.3 Personnel Resources

The most perplexing roadblocks in pursuit of data in the study came in the area of personnel resources. Some serious consideration should be given to establishing the capability at NMPC to recapture the historical data relating billets allowed versus billets filled on a ship-by-ship basis. It is understood that the problem is a difficult one, made more difficult by service number deletion from old records. Nevertheless, if a link between readiness and personnel resources exists, this information is crucial to its success.

7.1.4 CASREP Reporting System

Additional emphasis should be placed by squadron commanders to their ship commanding officers on the importance of the CASREP system. Downtime taken from the CASREPs and subsequently applied to the readiness formulas used, yielded substantially higher readiness values than those which appeared in the RM&A analysis, a six-system survey, cited in Section 7.0. Based on this data comparison, it is apparent that not all casualties that occurred were reported.

APPENDIX A

AN/SPS-48 RADAR SUMMARY

APPENDIX A

AN/SPS-48 RADAR SUMMARY

The AN/SPS-48 Radar set is a three-coordinate, height-finding, air-search, multiple-beam, frequency-scanning, computer-controlled, pulsed, S-band radar; which provides highly accurate range, elevation, and azimuth data. The radar search volume extends to over 200 nautical miles at a constant ceiling in excess of 80,000 feet. The scan coverage is stabilized for the pitch and roll movements of the ship and the effects of weather on the radar antenna and RF energy. The radar set is computer-programmed to provide virtually simultaneous, multiple-beam, elevation scanning. The antenna rotates at a constant rate of either 15 or 17 1/2 RPMs for azimuth scanning, while simultaneously scanning in elevation from the horizon to 45° above the horizon with computer-programmed grouped pencil beams. Video for Range-Height Indicators (RHI) and PPI displays and for digital range and height readouts are provided. Built-in test and status monitoring circuits are provided to indicate proper system operation.

The three systems examined in this analysis are similar in that the AN/SPS-48C(V) is basically an AN/SPS-48A(V) with ADT (Automatic Detection and Tracking) incorporated, and the AN/SPS-48A(V) is an AN/SPS-48(V) with the added capability provided by the installation of a Moving Target Indicator (MTI) group. The two latest variants (A and C) have nine operational modes: normal, passive-display, 5-degree, burn-through, chip-through, 3-pulse, 5-degree (long range), 4-pulse 45 degree (short range (MTI), while the original AN/SPS-48(V) lacks the MTI modes.

The major assemblies compromising the AN/SPS-48(V) Radars are: (1) the antenna group; (2) the transmitter group; (3) the frequency control group; (4) the receiver group; (5) the programmer group; (6) the data stabilization computer; (7) the moving target indicator group (SPS-48(A) and (C) only; (8) the radar set consoles; and (9) the Automatic Detection and Tracking (ADT) processor (SPS-48C(V) only).

The antenna group compromises the antenna system and consists of four major subassemblies. The radar antenna is composed of 76 horizontally positioned linear arrays stacked one on top of the other and is tilted back at a 15° angle. The reference antenna is a piece of S-band waveguide shaped like an inverted "L". At the radiating end, the waveguide is covered by a radome which permits pressurization and prevents entrance of moisture. It is located on top of the antenna support between the IFF antenna and the boresight mount. The remaining subassemblies are the dual-operative IFF antenna and the antenna pedestal which consists of two gearbox drive assemblies, a data takeoff assembly, a rotary coupler, and a main drive gear.

The transmitter group, housed in several equipment bays, encompasses the transmitter system, with the exception of the first RF stage components housed with the frequency control group. The transmitter group also contains water-cooled heat exchangers, the coaxial and waveguide systems, and a dummy load. The frequency control group houses the synthesizer system, part of the transmitter group mentioned previously, and various power supply system assemblies. The receiver group contains the receiver system with the exception of the front end assemblies contained in the transmitter bays.

The programmer group, part of the functional computer system, also contains the signal data converter and the Scott-Tee power supply. The computer system also contains the data stabilization computer. The Moving Targer Indicator (MTI) group houses the functional MTI system, with the exception of the MTI control box which is mounted with the radar set consoles to provide remote control of the MTI system. The Radar Set Consoles (RSCs) house the three types of range-height indicators required for the functional display system. The final major component of the SPS-48 Radar set is the Automatic Detection and Tracking (ADT) processor found on the SPS-48C(V) and is utilized as part of the SM-2 missile system. The ADT control box is mounted above the 49-master PPI and provides remote control and remote error display of the ADT system.

Appendix B

Scatter Diagrams

80/05/28. 23.23.44. PAGE 2

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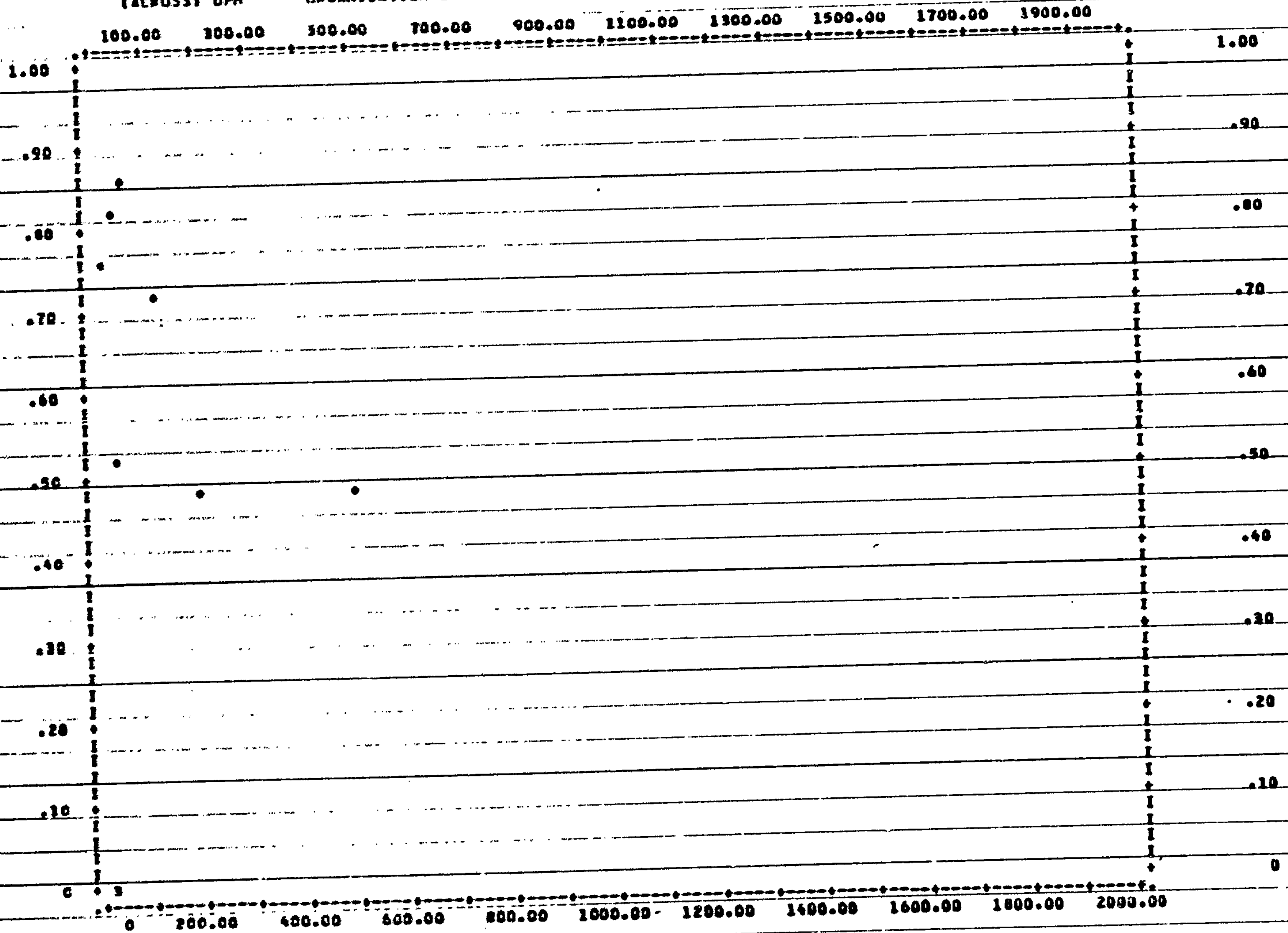

CIRC
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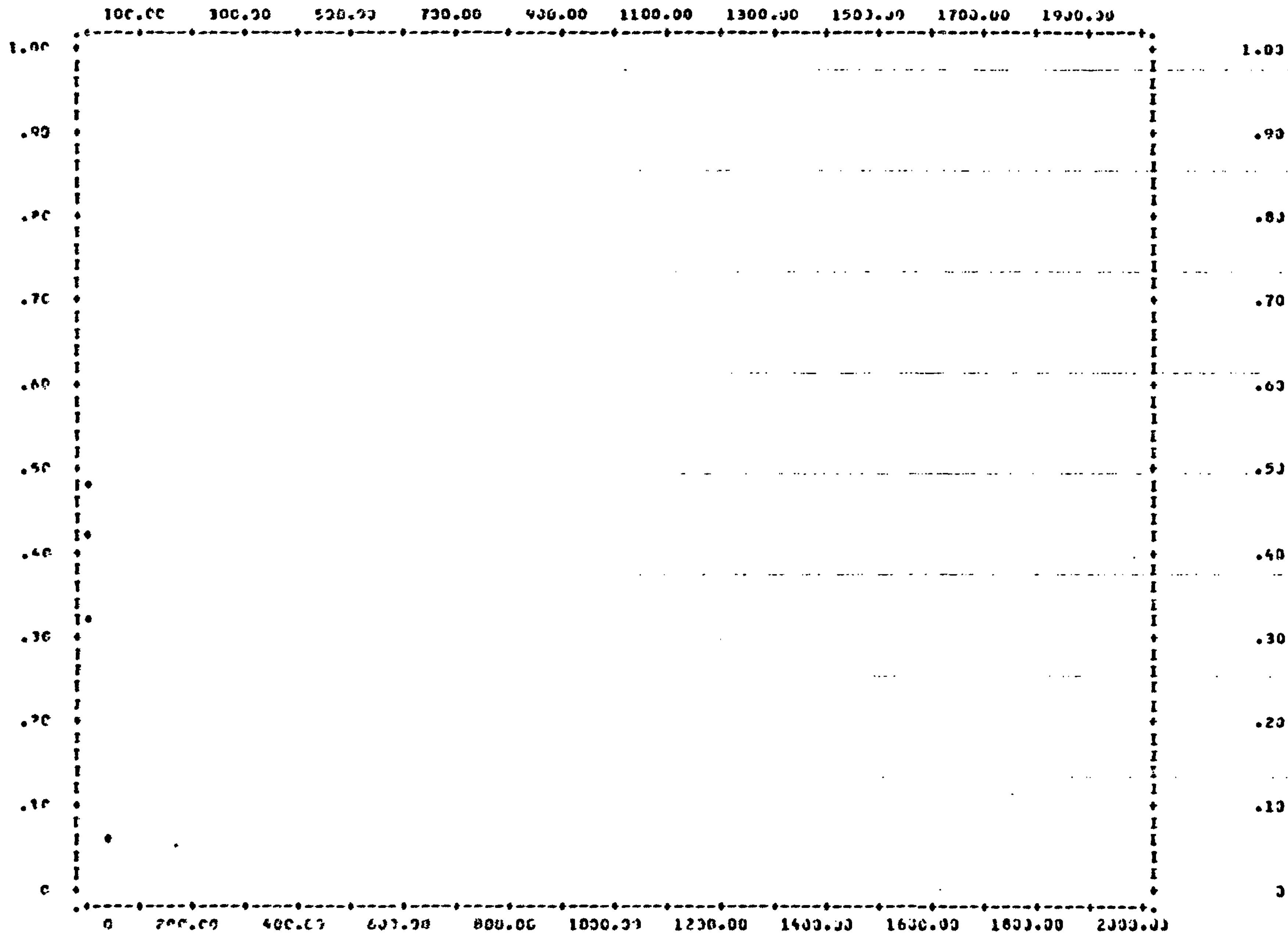
FILE SPSIPOO (CREATION DATE = 83/05/15.)

80/05/28. 23.22.39. PAGE 2

SCATTERGRAM OF (DOWN) PJ READINESS)
(ACROSS) OPH ORGANIZATIONAL MANHOURS



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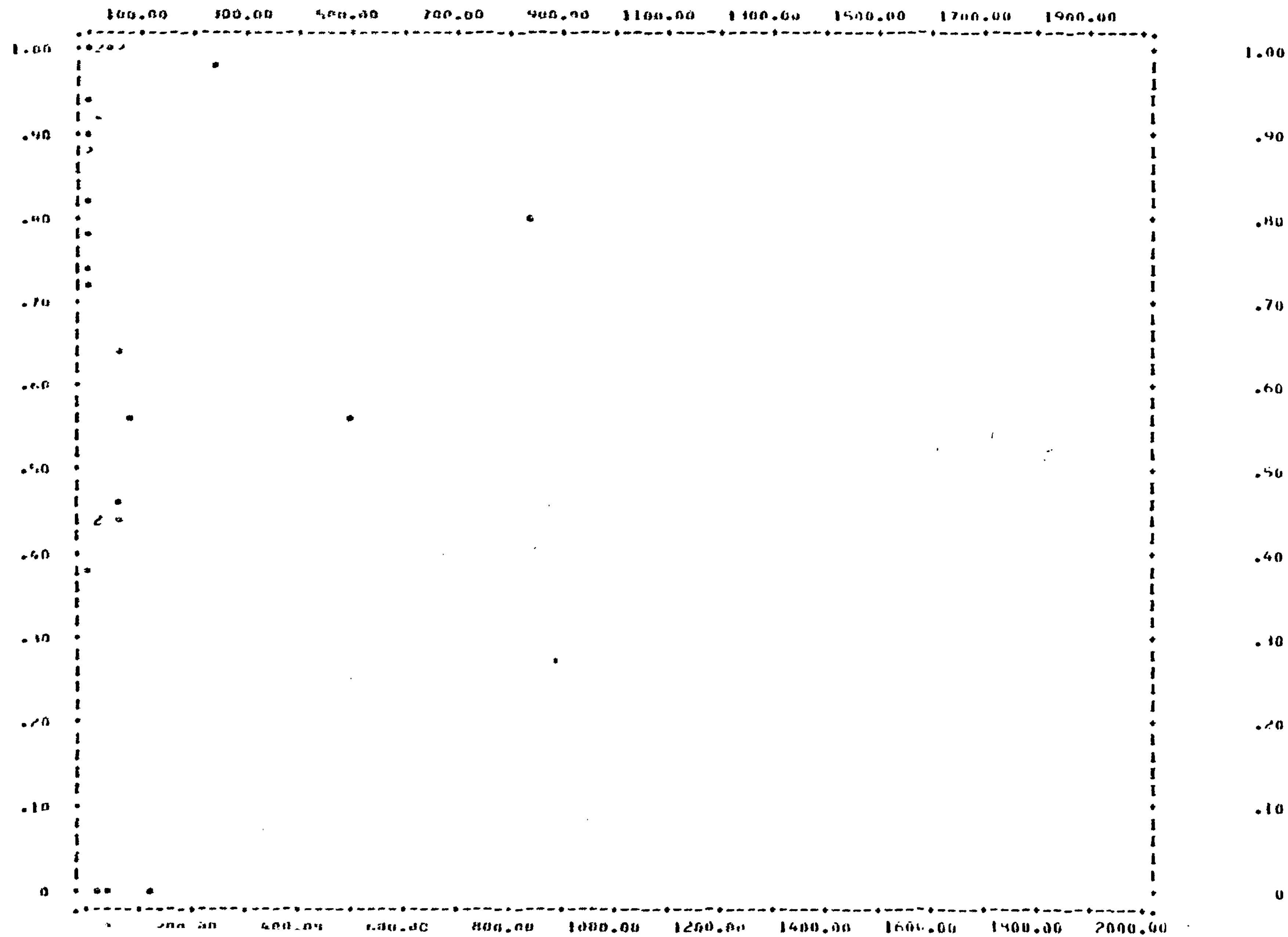
FILE SPSS... (CREATION DATE = 80/05/15.)

SCATTERGRAM OF (DOWN) R2 READINESS2
(ACROSS) OXH ORGANIZATIONAL BARRIERS



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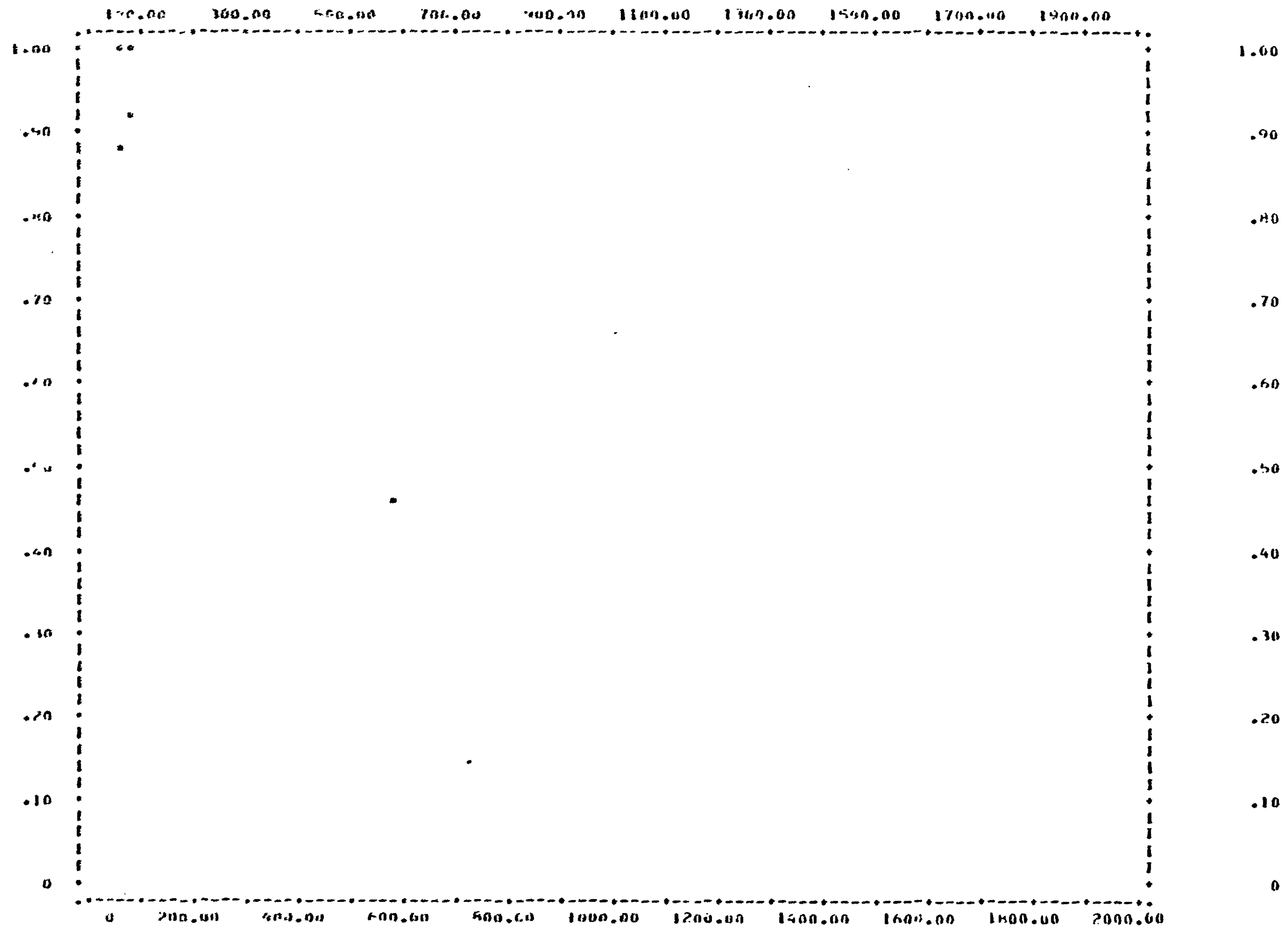
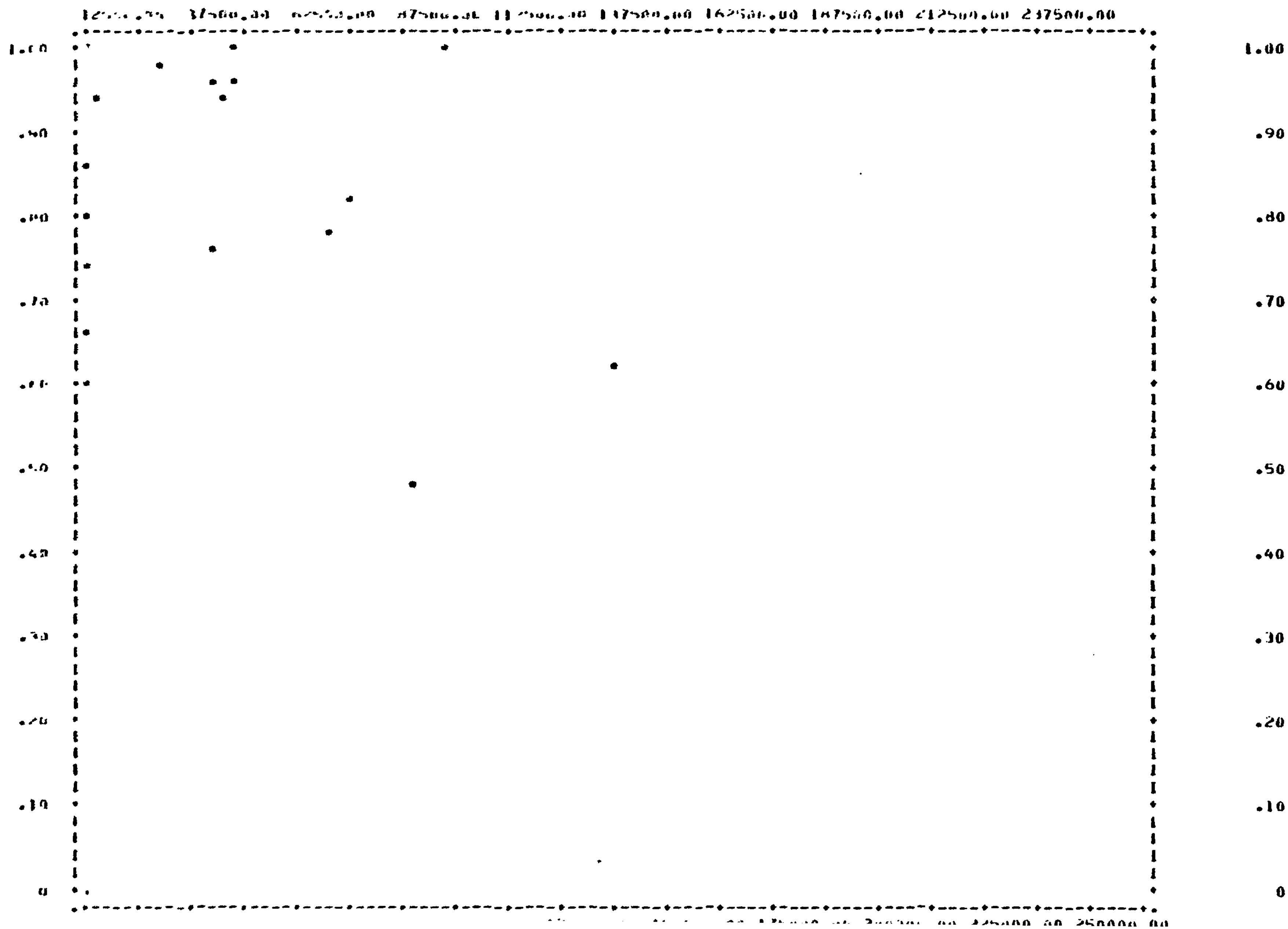
FILE SPSS... (CREATION DATE = ...)   08/05/79.   15.37.49.   PAGE 2

SCATTERGRAM OF (DOWN) R2 READINESS2
(ACROSS) DRR ORGANIZATIONAL HANDBOOKS



PAGE 2

SCATTERGRAM OF



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SCATTERGRAM OF (DOWN) PT (ACROSS) OPTS

80/05/23. 16.53.44. PAGE 2

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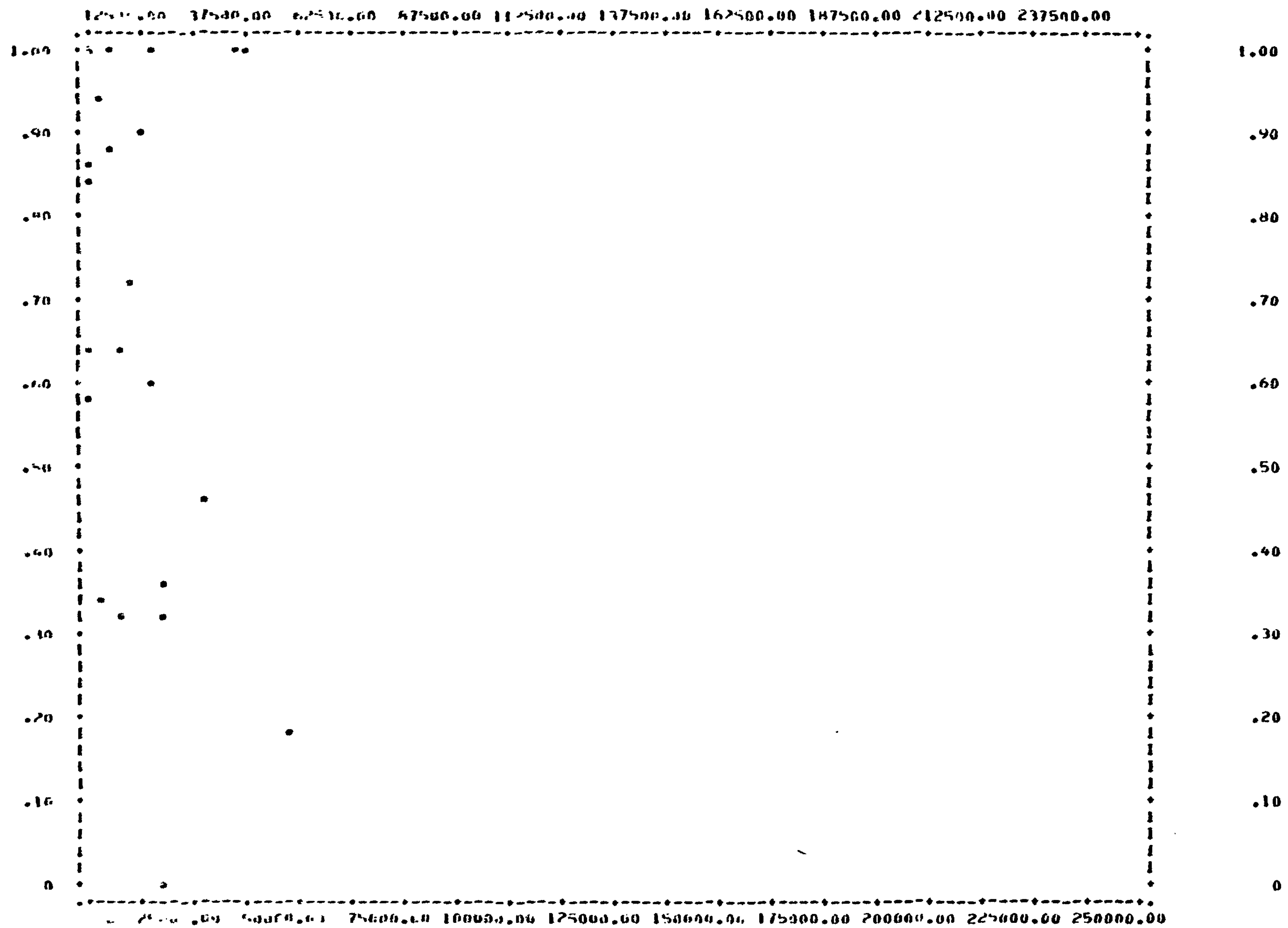

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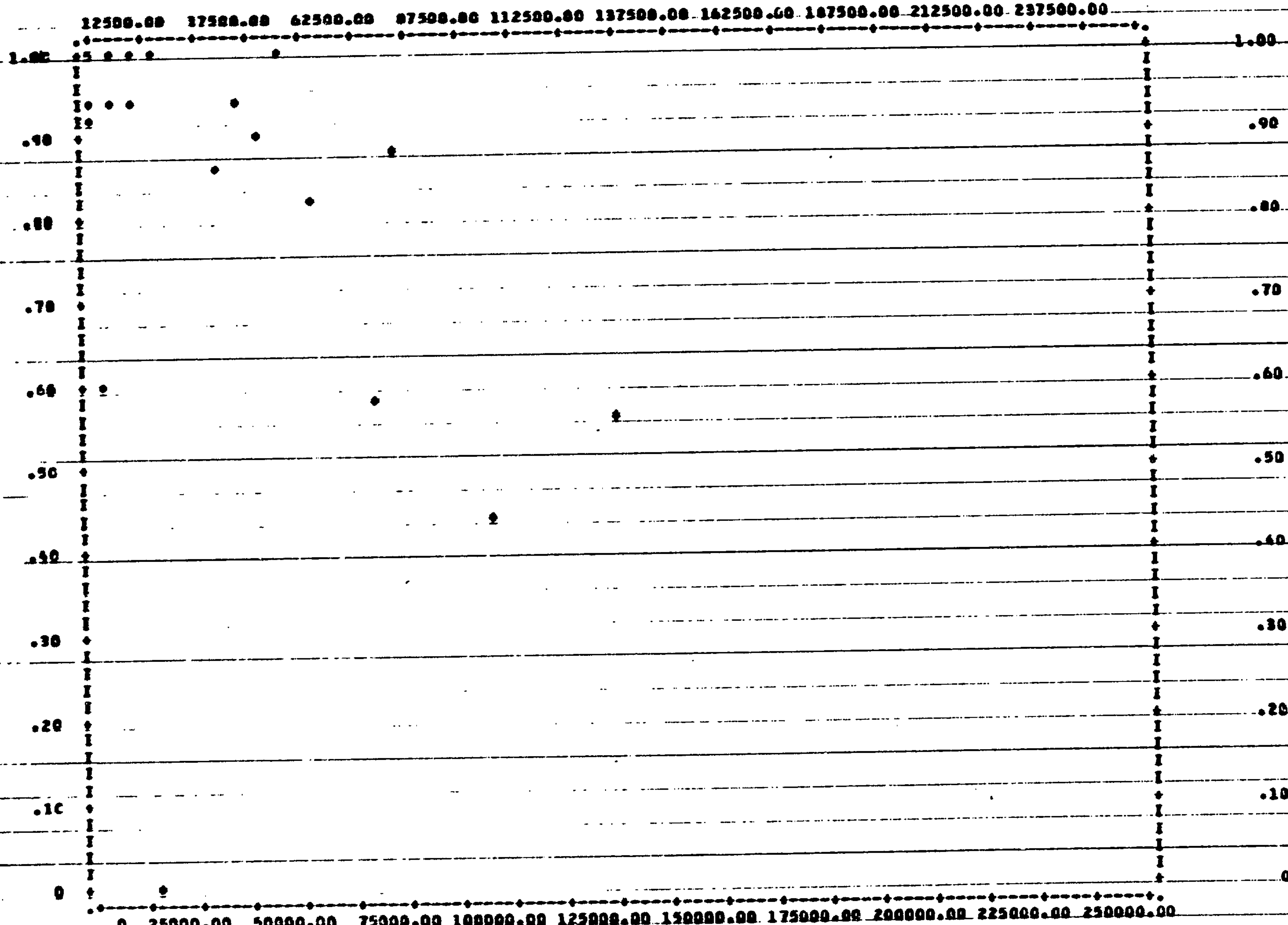
(ACROSS) OPTS ORGANIZATIONAL PARTS EXPENDITURES



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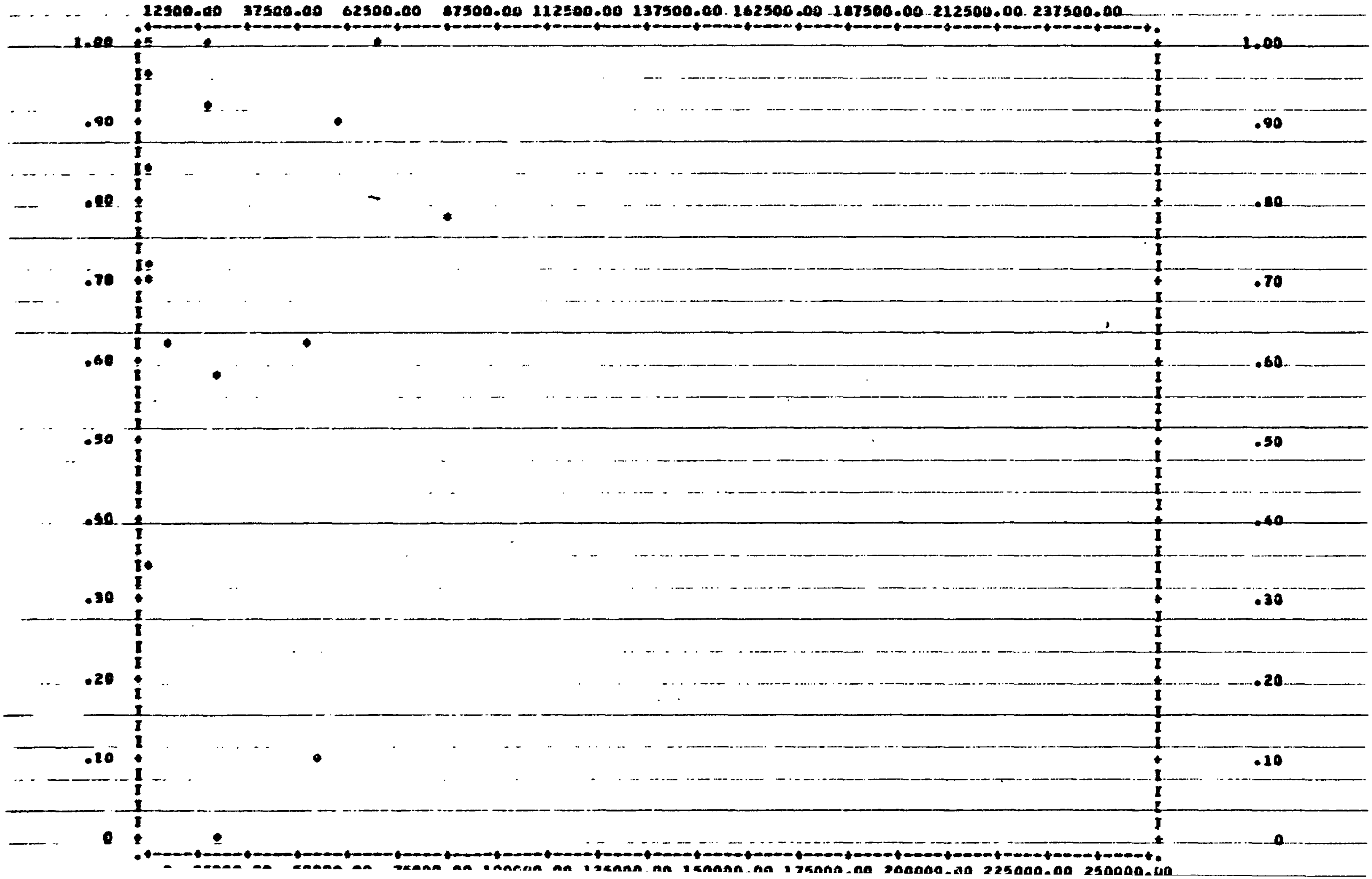
80/05/28. 22.38.55. PAGE 2

SCATTERGRAM OF (DOWN) R2 READINESS2
(ACROSS) OPTS ORGANIZATIONAL PARTS EXPENDITURES



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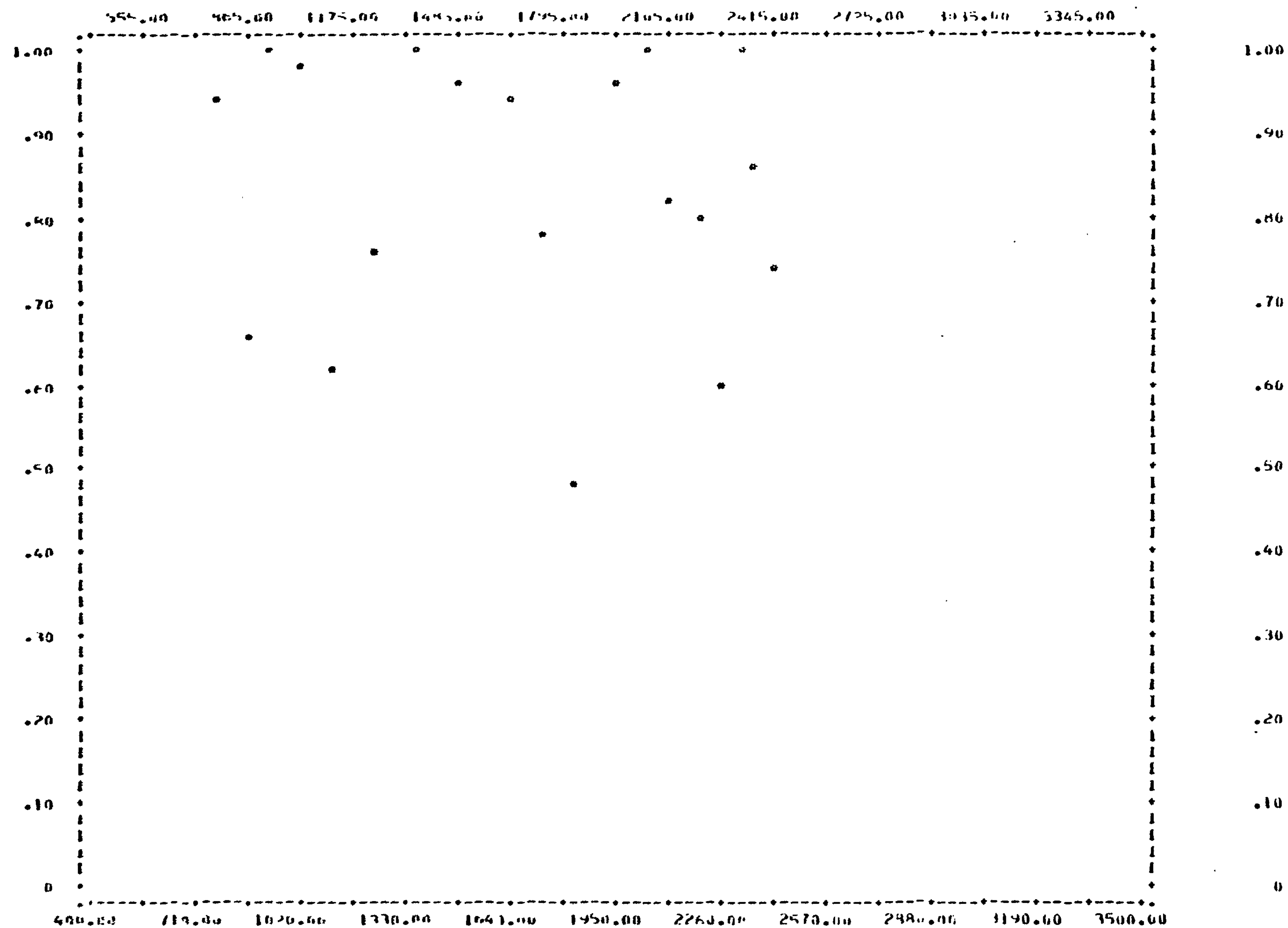

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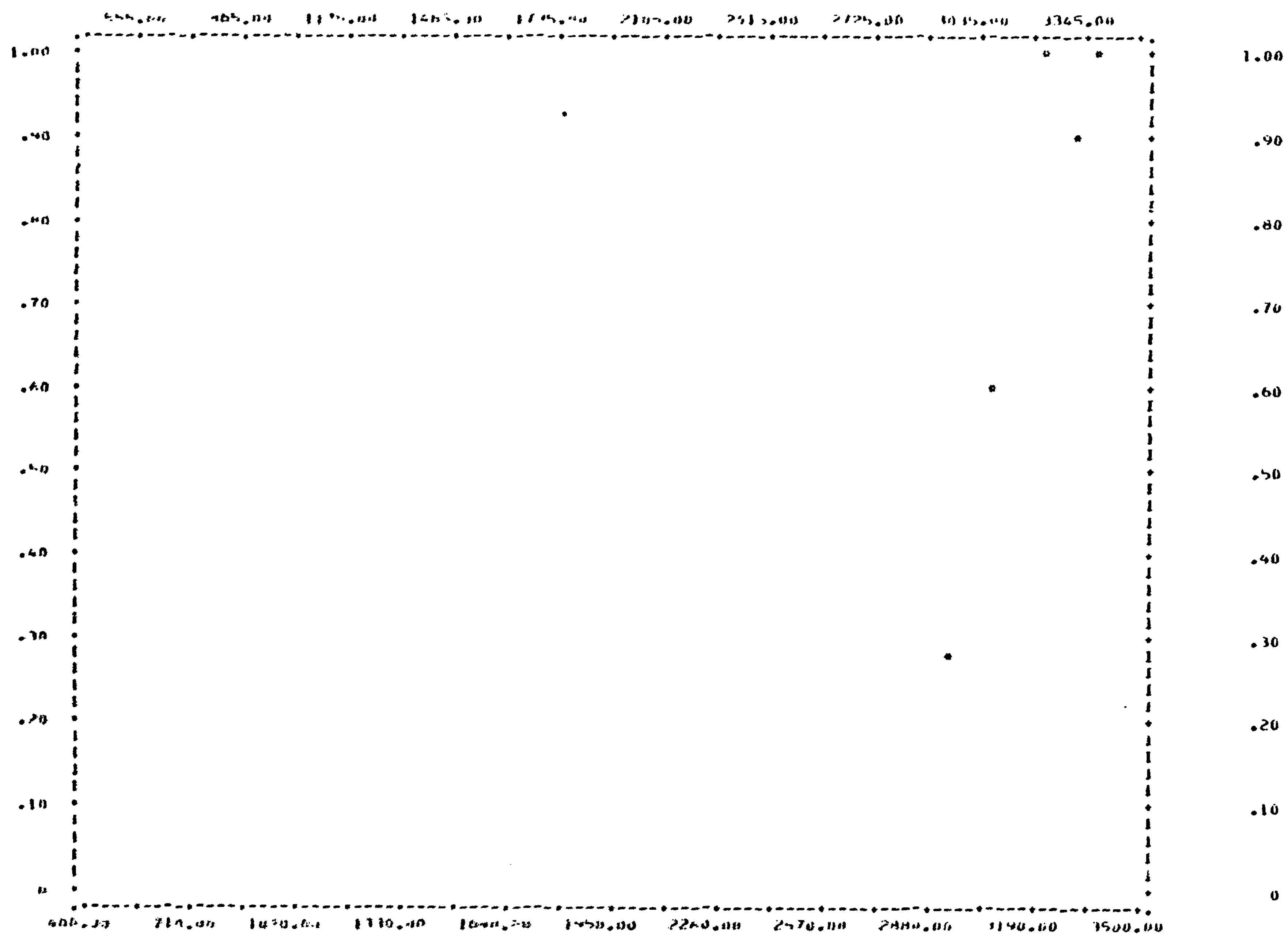
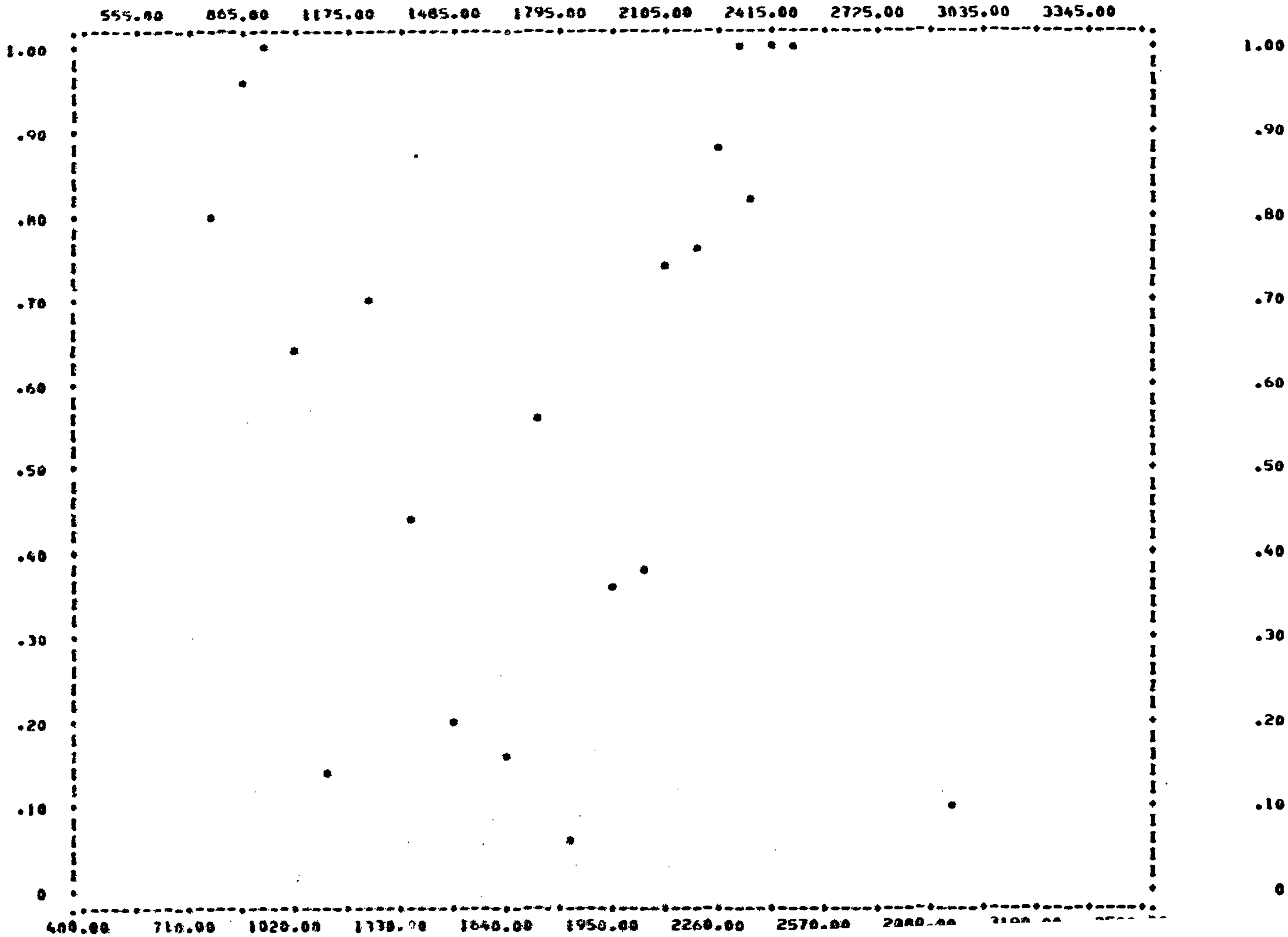
SCATTERGRAM OF



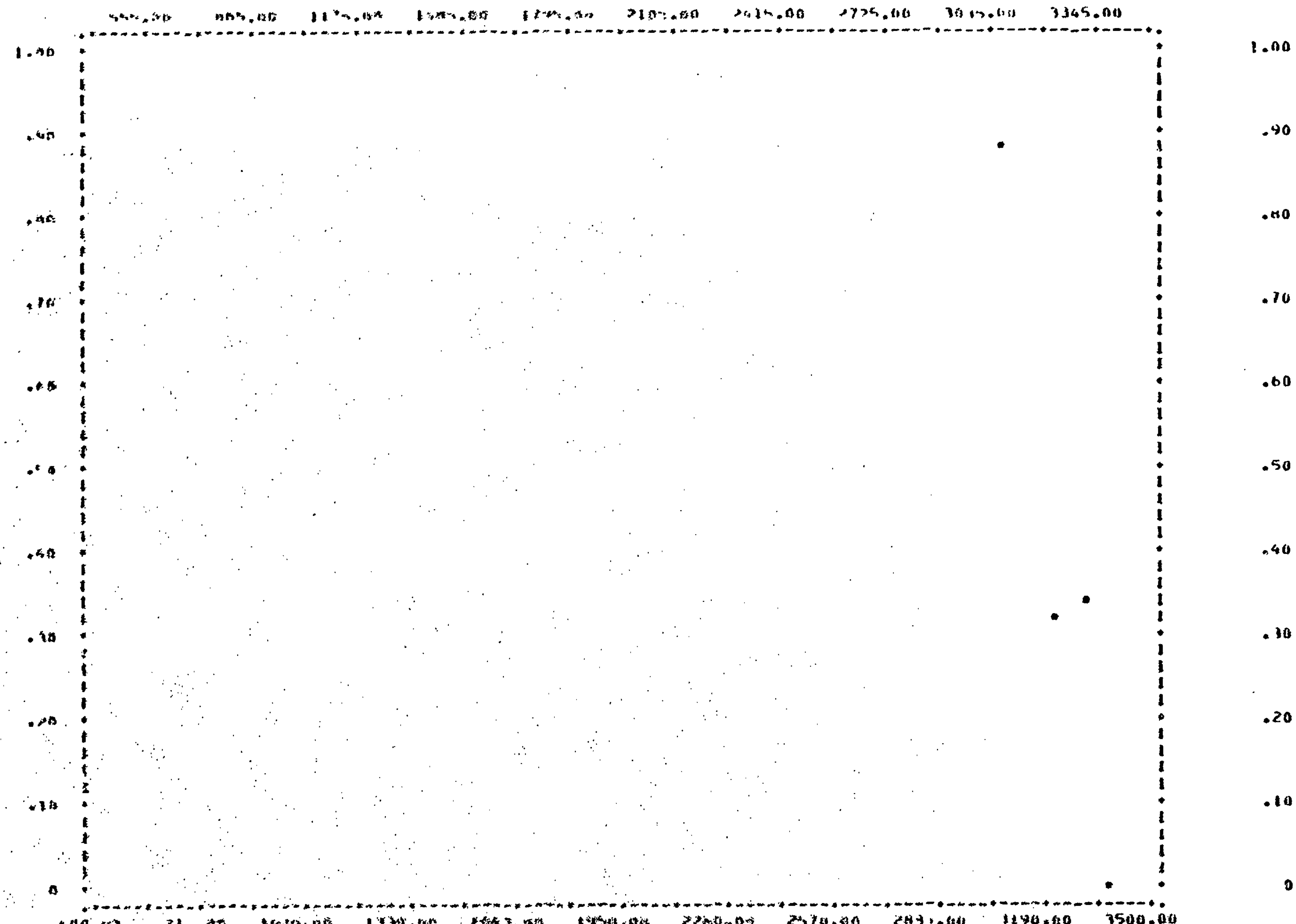
CIAV
SELECT CIAV ONLY
FILE SPSIPYO (CREATION DATE = 80/05/15.)   80/05/28.   11.31.30.   PAGE 2

SCATTERGRAM OF (DOWN) R2 READINESS2
(ACROSS) R3 PERIOD MIDPOINT DAYS



PAGE 2

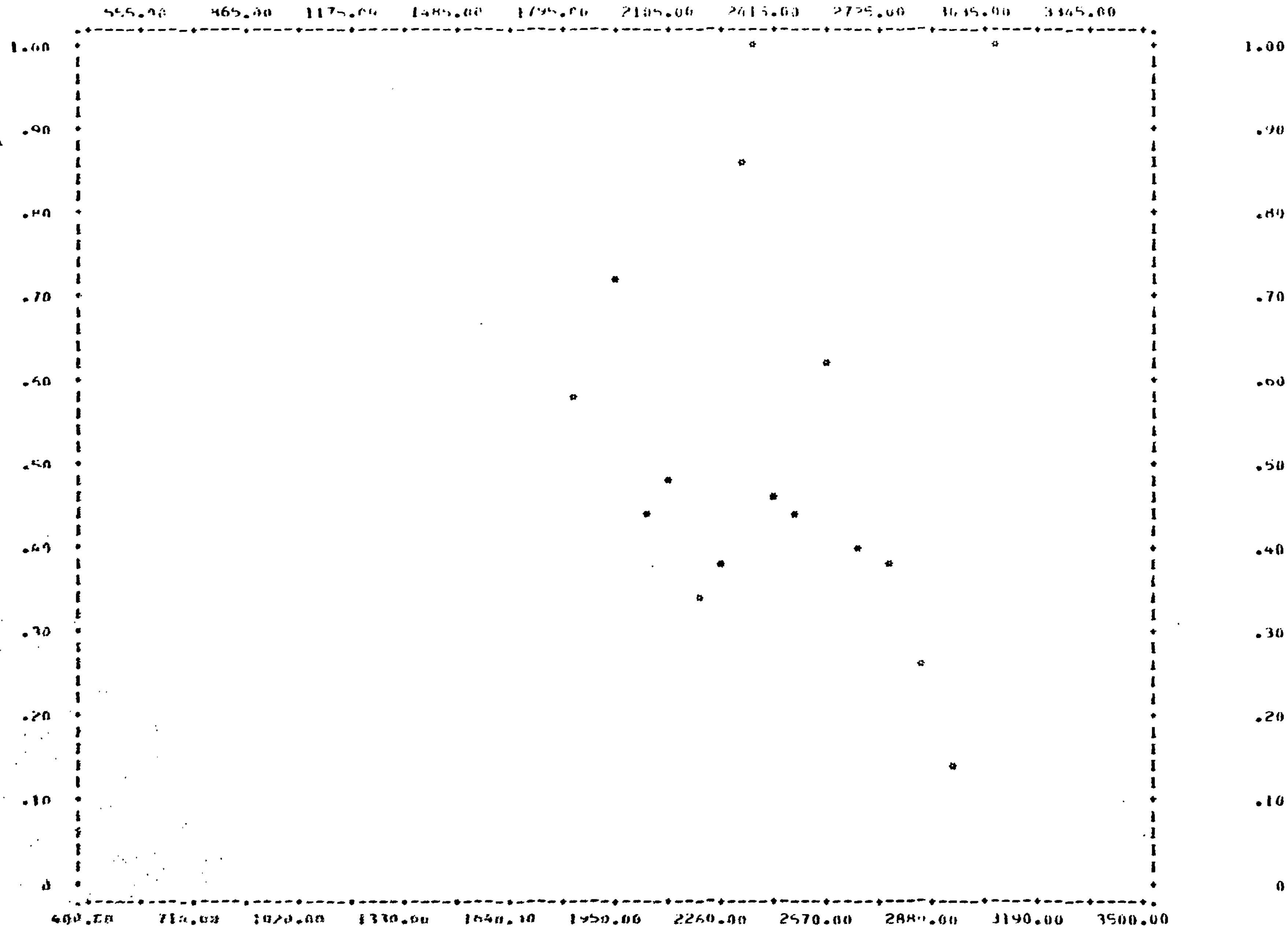
(ACROSS) PERIOD MIDPOINT DAYS



AI A
SELECT AI A ONLY
FILE SPS1890 (CREATION DATE = 80/05/15.)
SCATTERGRAM OF (DOWN) RI READINESS

80/05/27. 17.24.37. PAGE 2

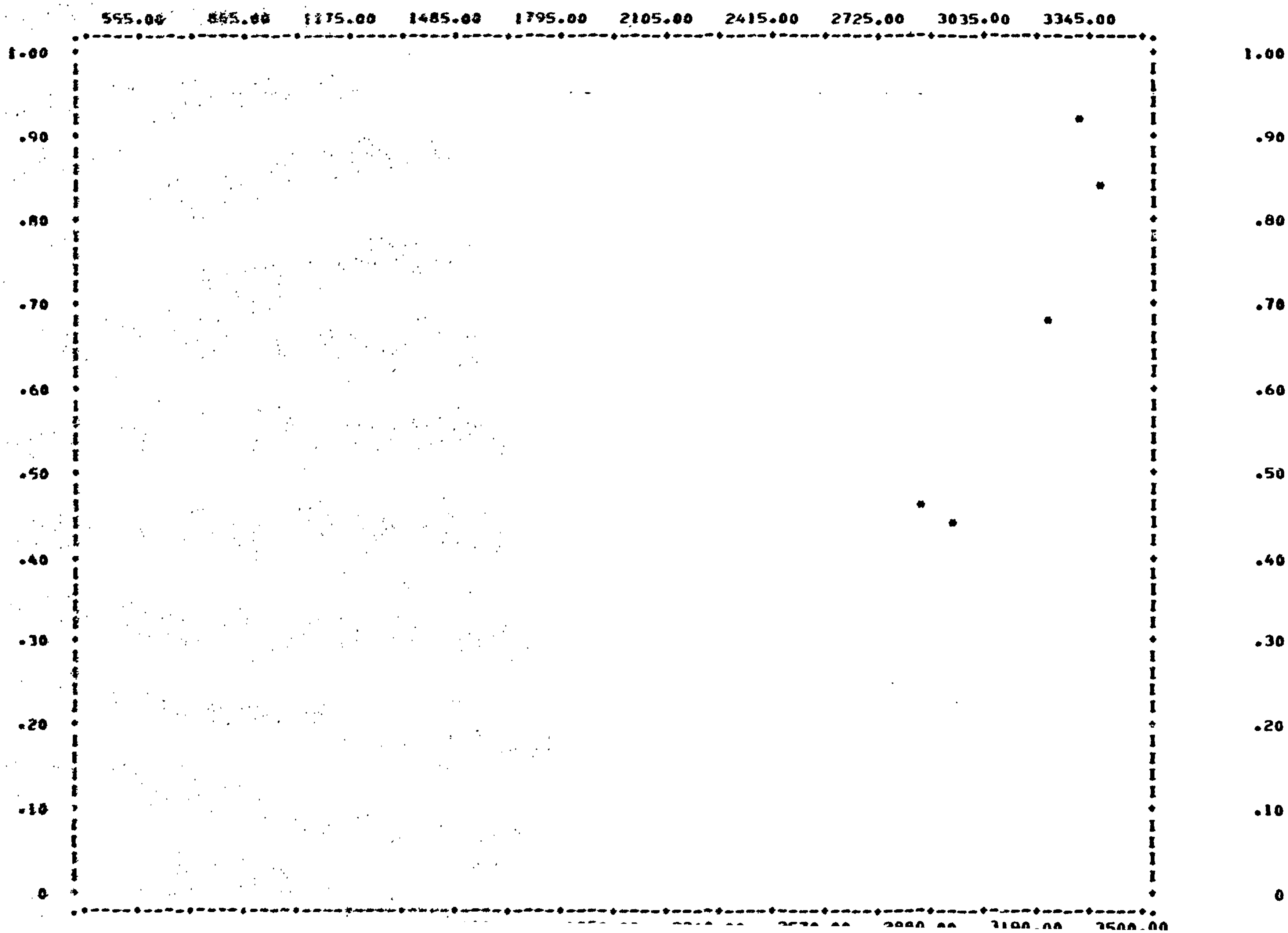
(ACROSS) 23 PERIOD MIDPOINT DAYS



E3 C
SELECT E3 C ONLY
FILE SPSIP90 (CREATION DATE = 80/05/15.)

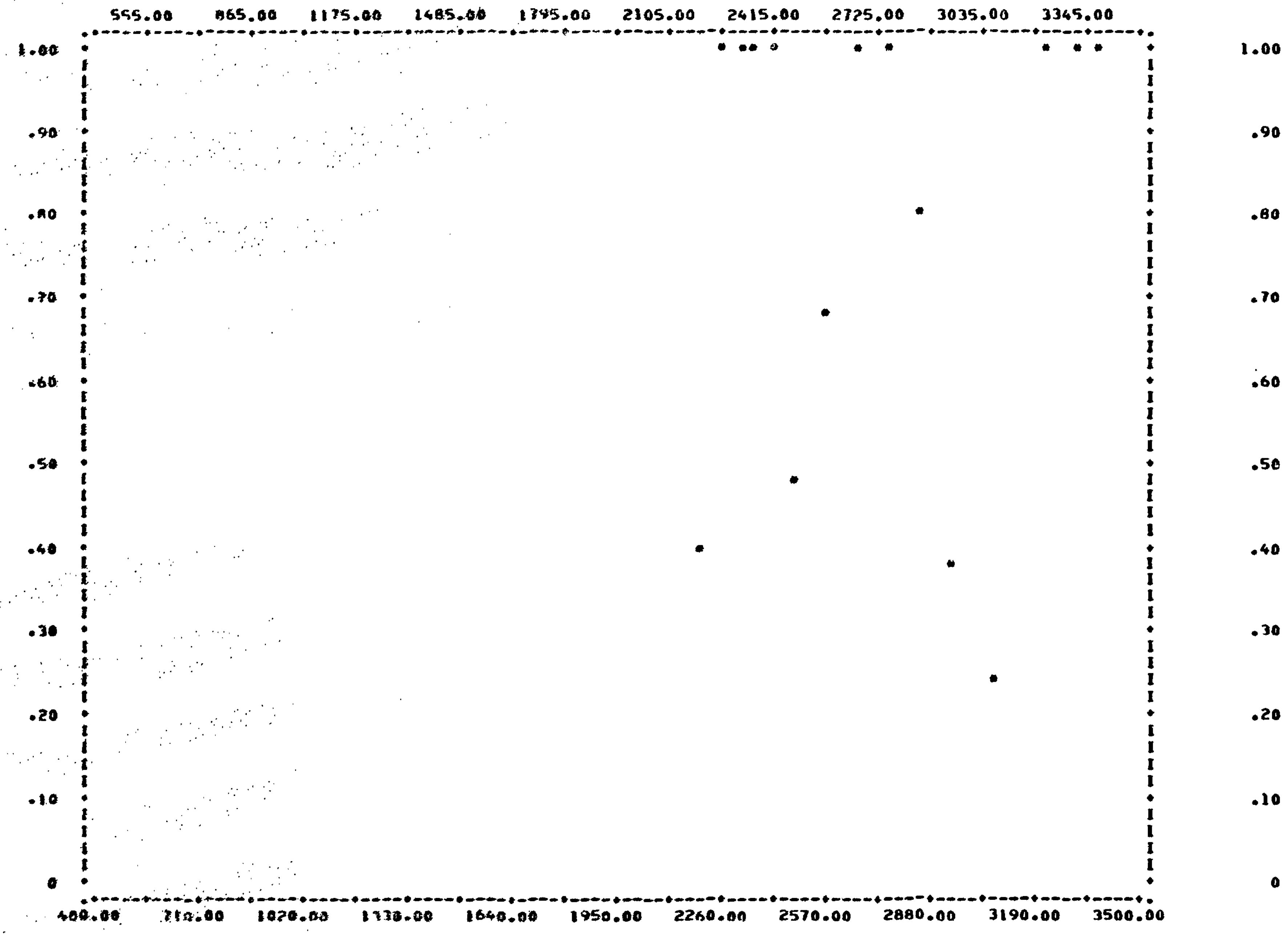
80/05/28. 15.13.03. PAGE 2

SCATTERGRAM OF (DOWN) R1 READINESS1
(ACROSS) R3 PERIOD MIDPOINT DAYS



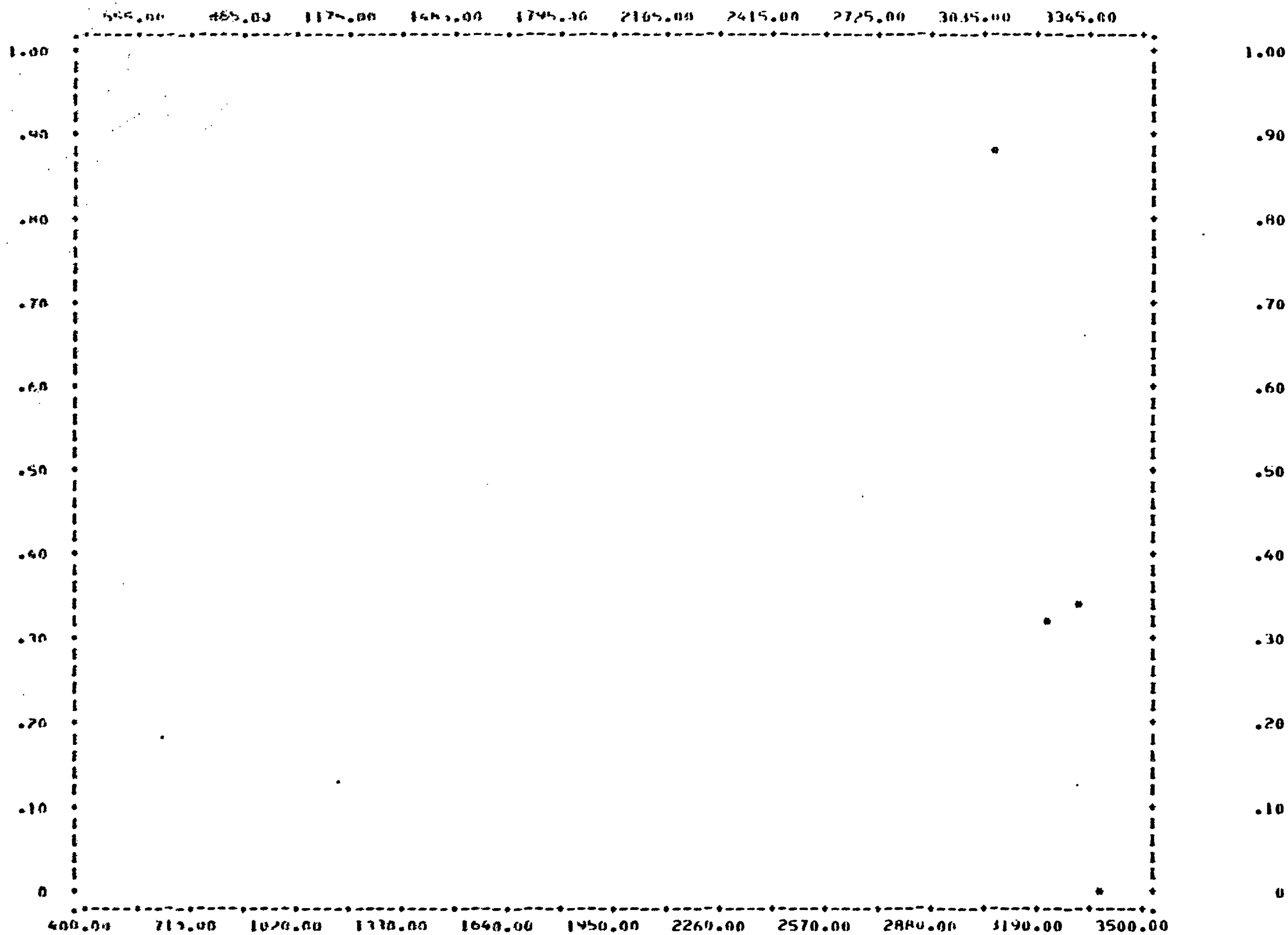
SELECT IF (M3 A ONLY)
FILE SPSIP90 (CREATION DATE = 80/05/15.)

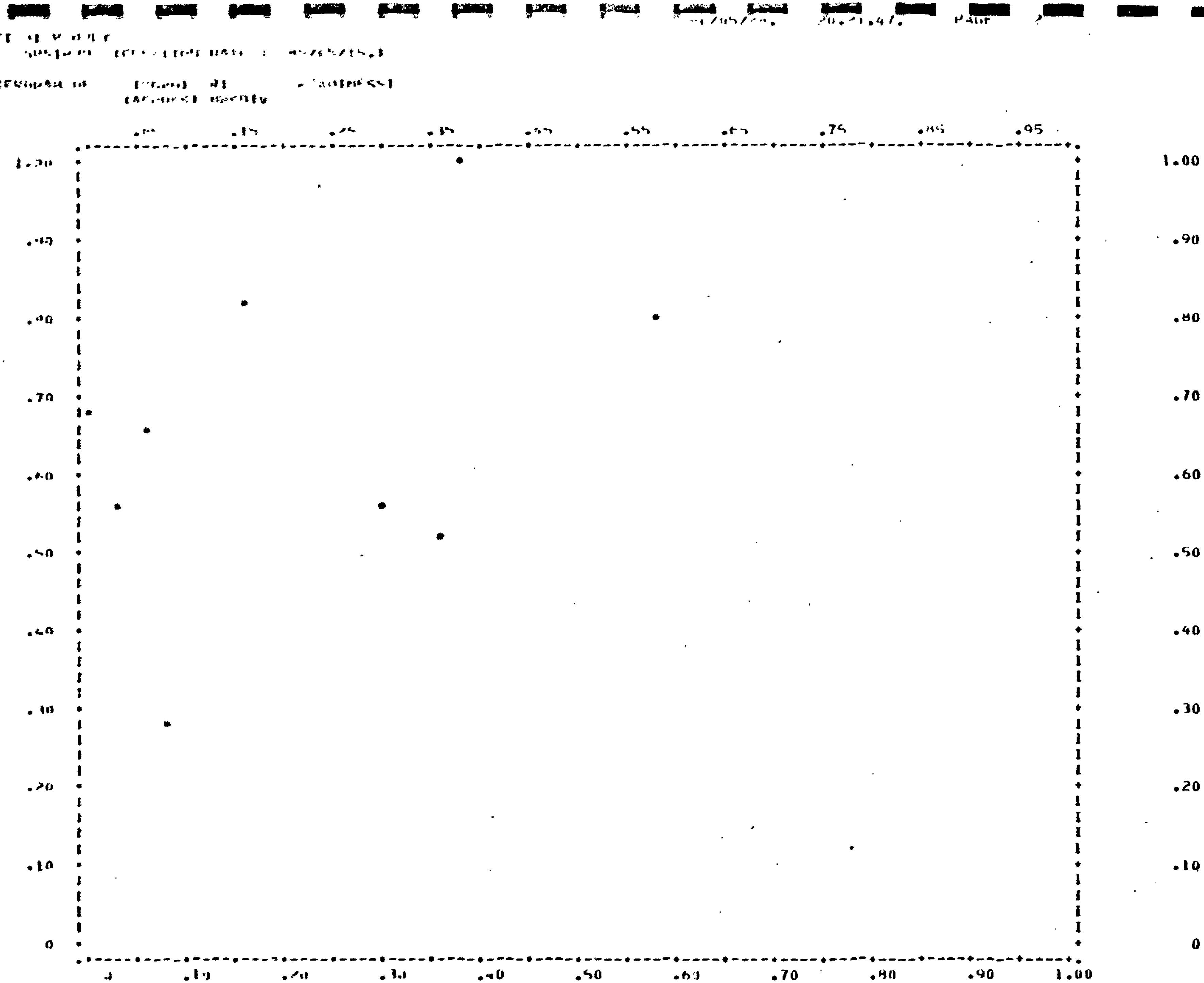
SCATTERGRAM OF (DOWN) R2 READINESS2
(ACROSS) R3 PERIOD MIDPOINT DAYS



F2 C
SELECT IF C ONLY
FILE NOSTRNO (CREATION DATE = 80/05/15.)
SCATTERGRAM OF (DOWN) R2 READINESS2 (ACROSS) R3 PERIOD MIDPOINT DAYS

80/05/23. 10.41.27. PAGE 2

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CLAY
SELECT CLAY ONLY
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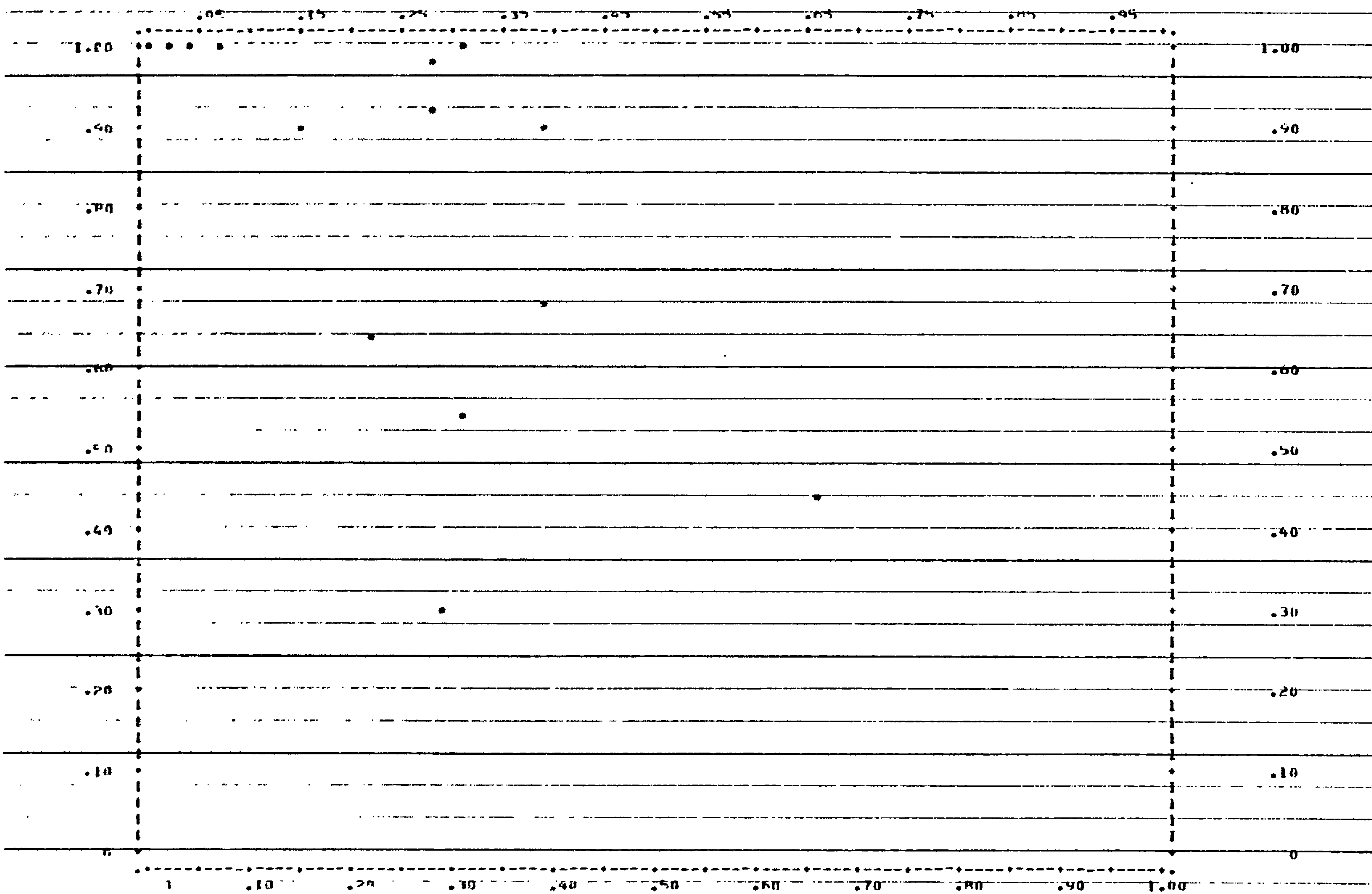
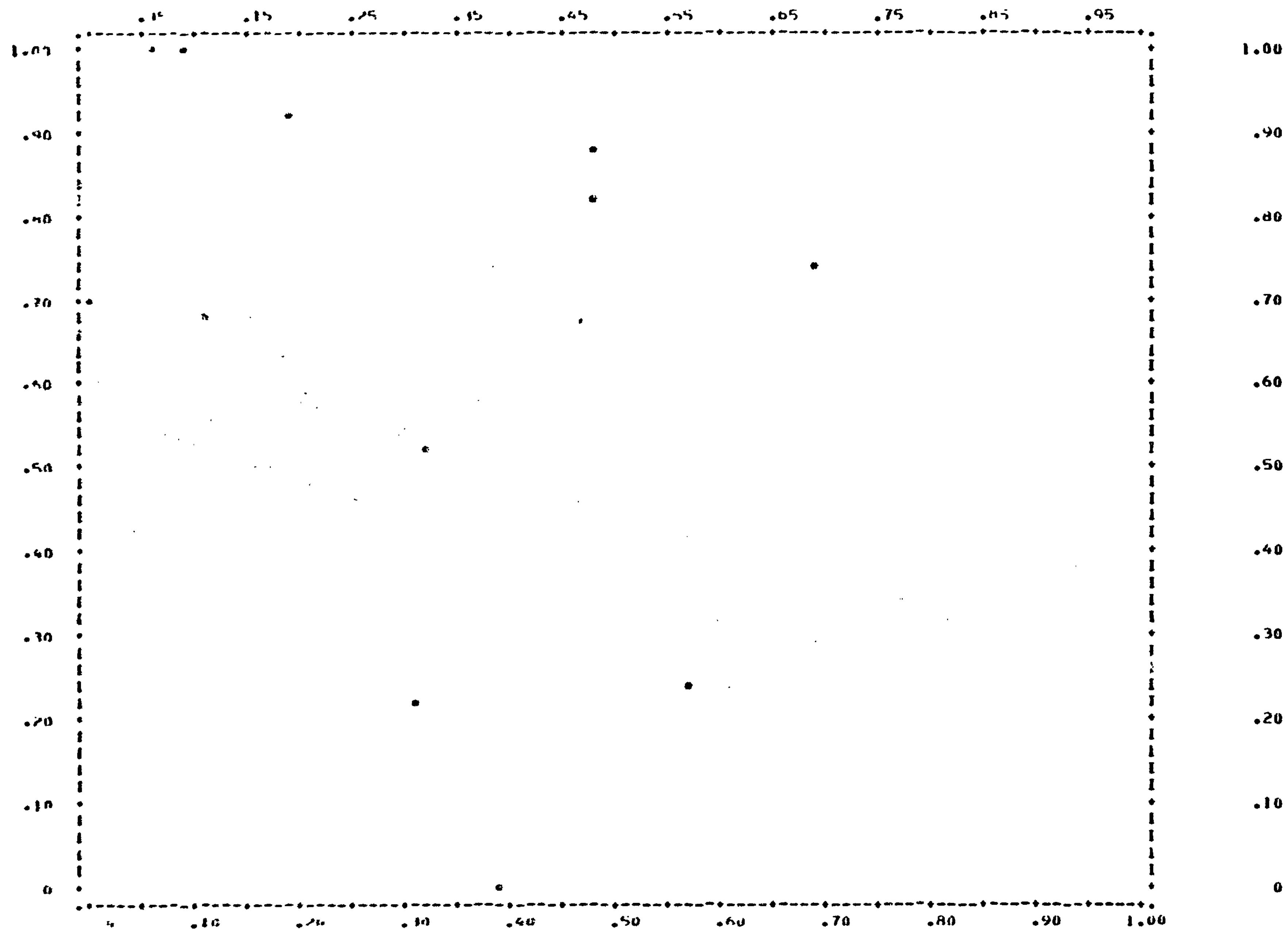
SCATTERGRAM OF (DOWN) [illegible] (ACROSS) [illegible]

56/05/27. 19.4 .42. PAGE 2



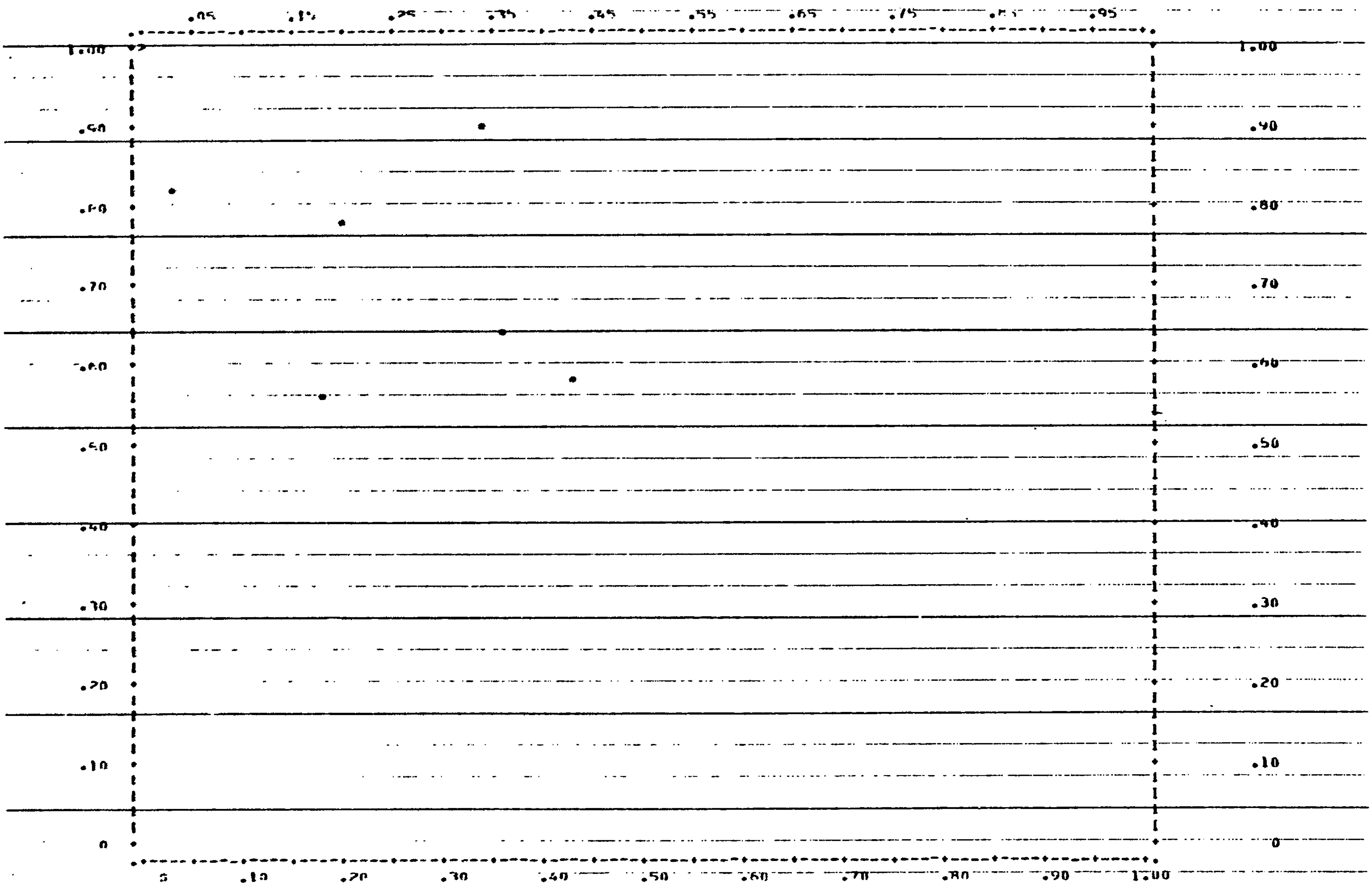
AS 4 80/05/24. 12.5?.44. PAGE 2
SELECT AS A ONLY
FILE SPSIMO (CREATION DATE = 80/05/15.)
SCATTERGRAM OF (DOWN) R2 (ACROSS) HRSDIV



CL A
SELECT CL A ONLY
FILE SOSIDSO (CREATION DATE = 80/05/15.)

80/05/27. 20.17.11. PAGE 2

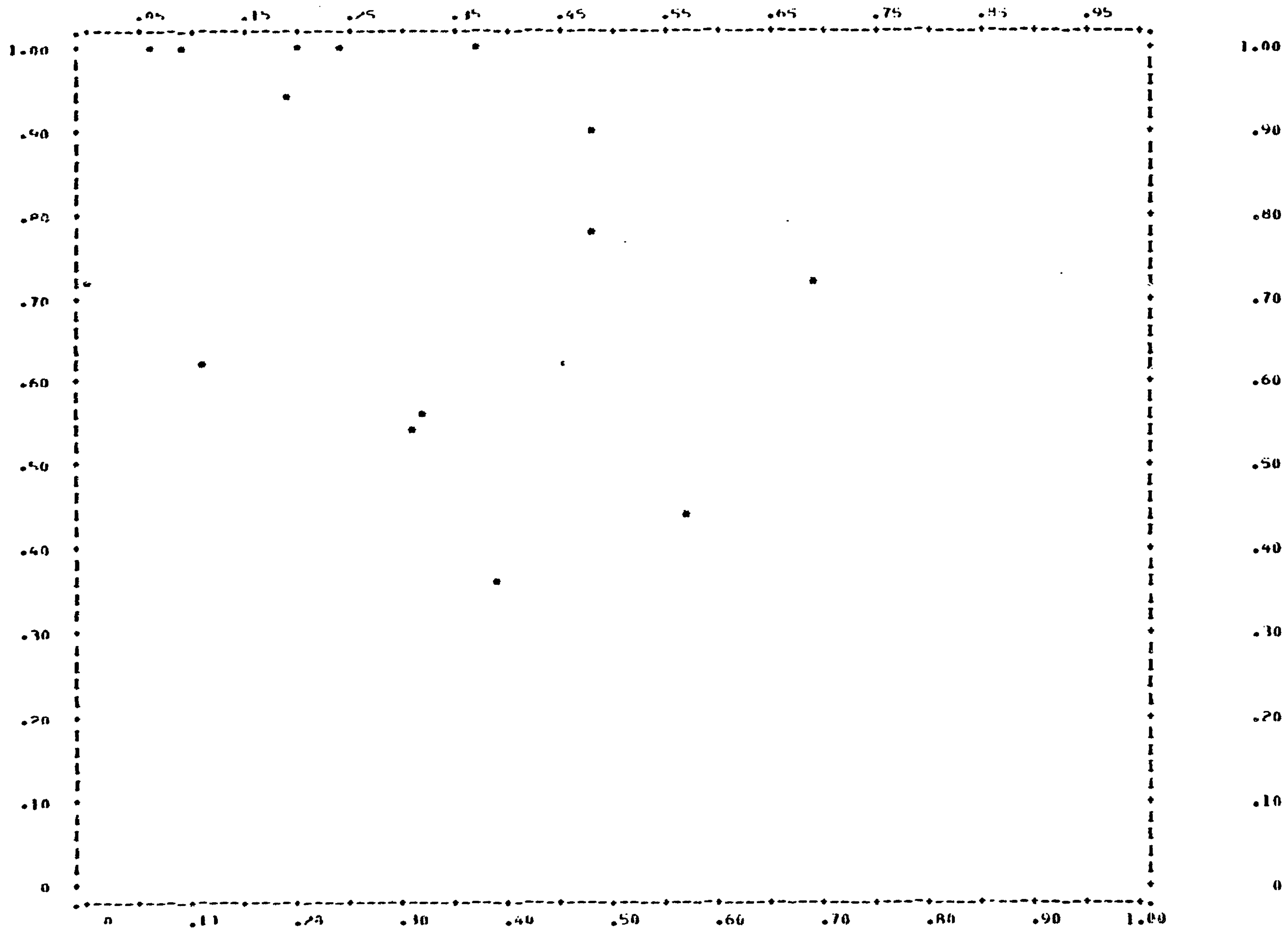
SCATTERGRAM OF (DOWN) R2 READINESS
(ACROSS) MHSDIV



AS A
SELECT AS A ONLY
FILE SPSIPP (CREATION DATE = 80/05/15.)
SCATTERGRAM OF (DOWN) X1 READINESS

80/05/23. 13.1?.18. PAGE 2

(ACROSS) HRSDIV



3F V
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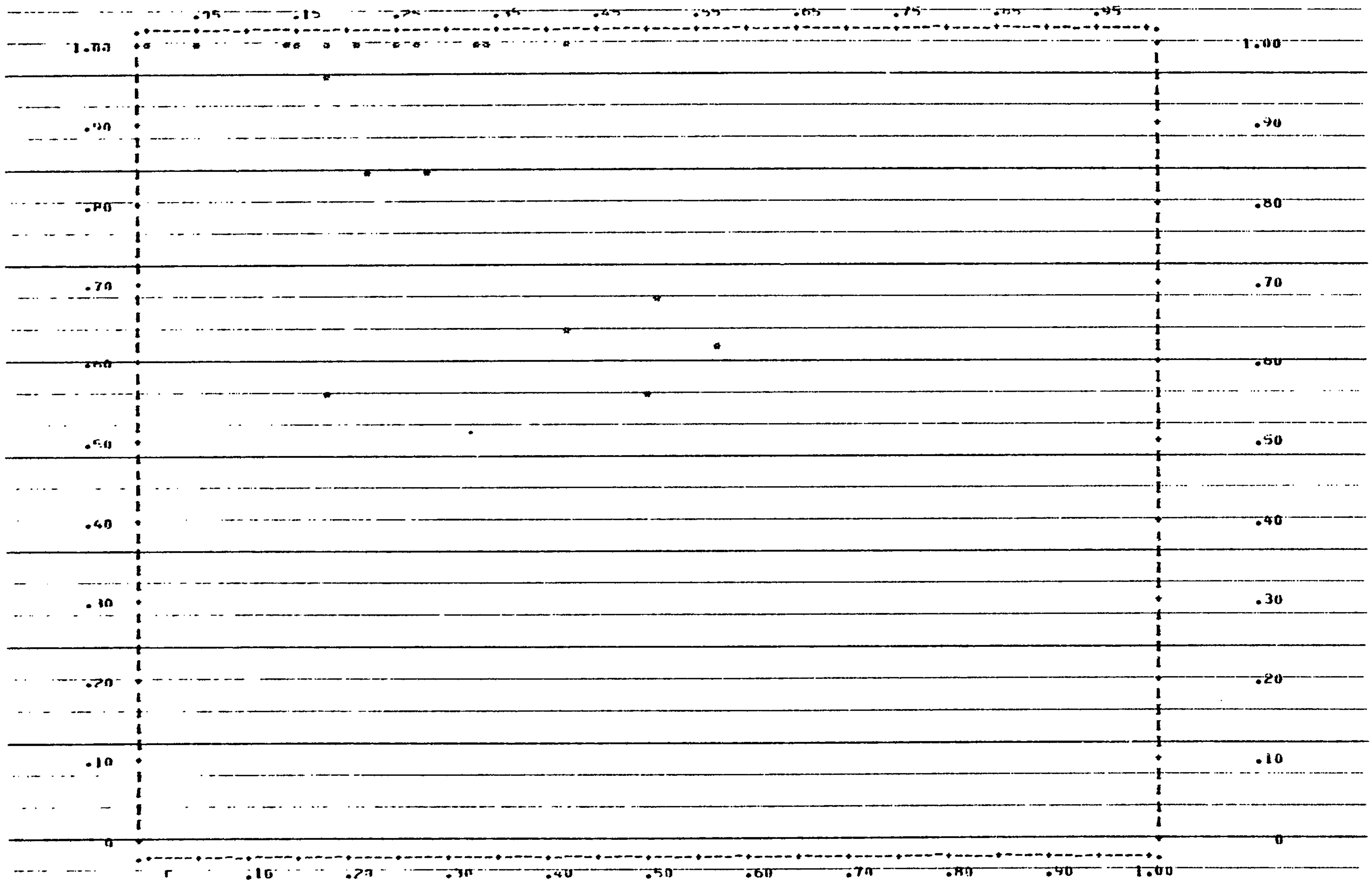
FILE SPSIPNO (CREATION DATE = 86/05/15.)
SCATTERGRAM OF (DOWN) ... (ACROSS) ...

07/05/27. 18.27.15. PAGE 2



FS A
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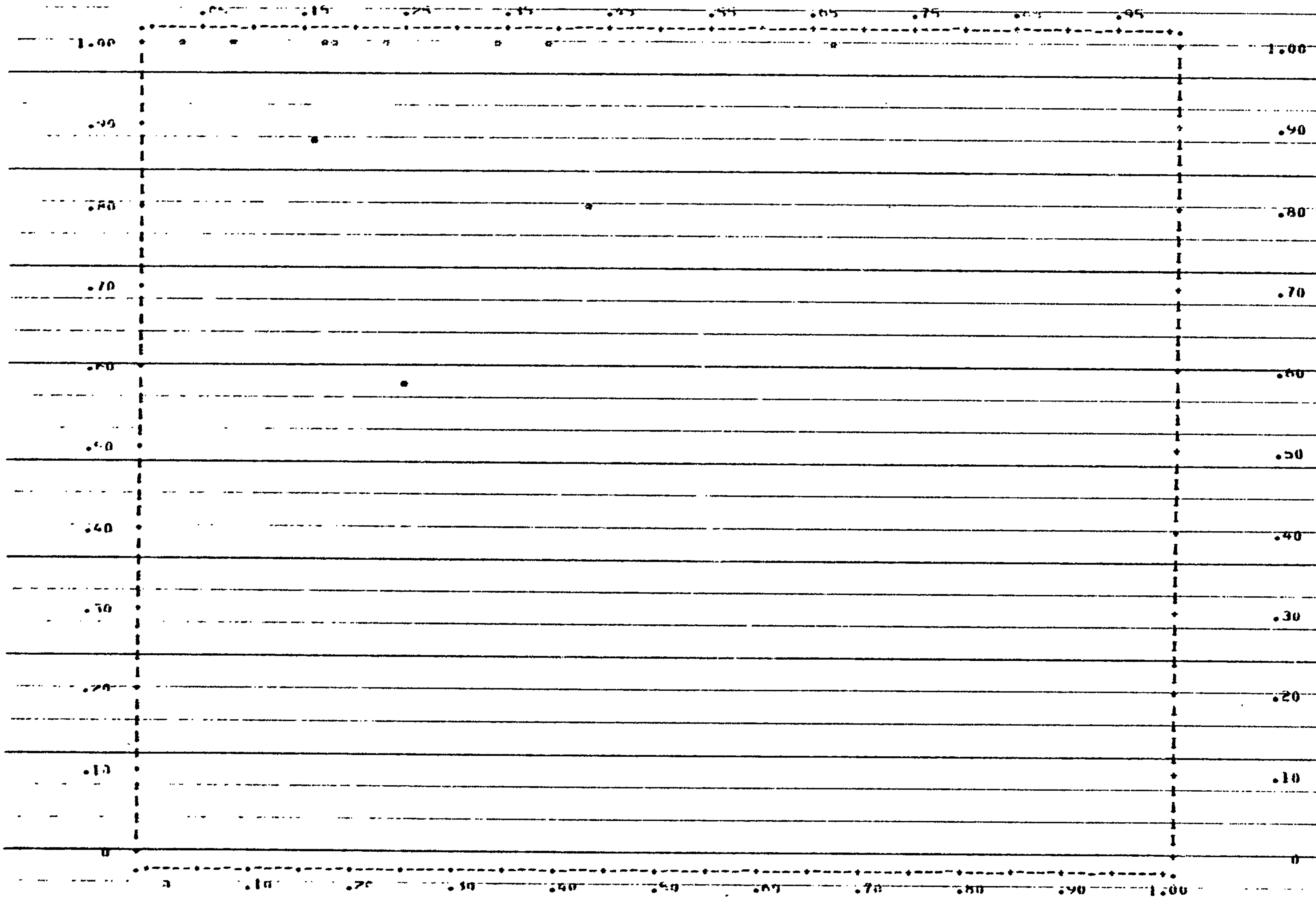
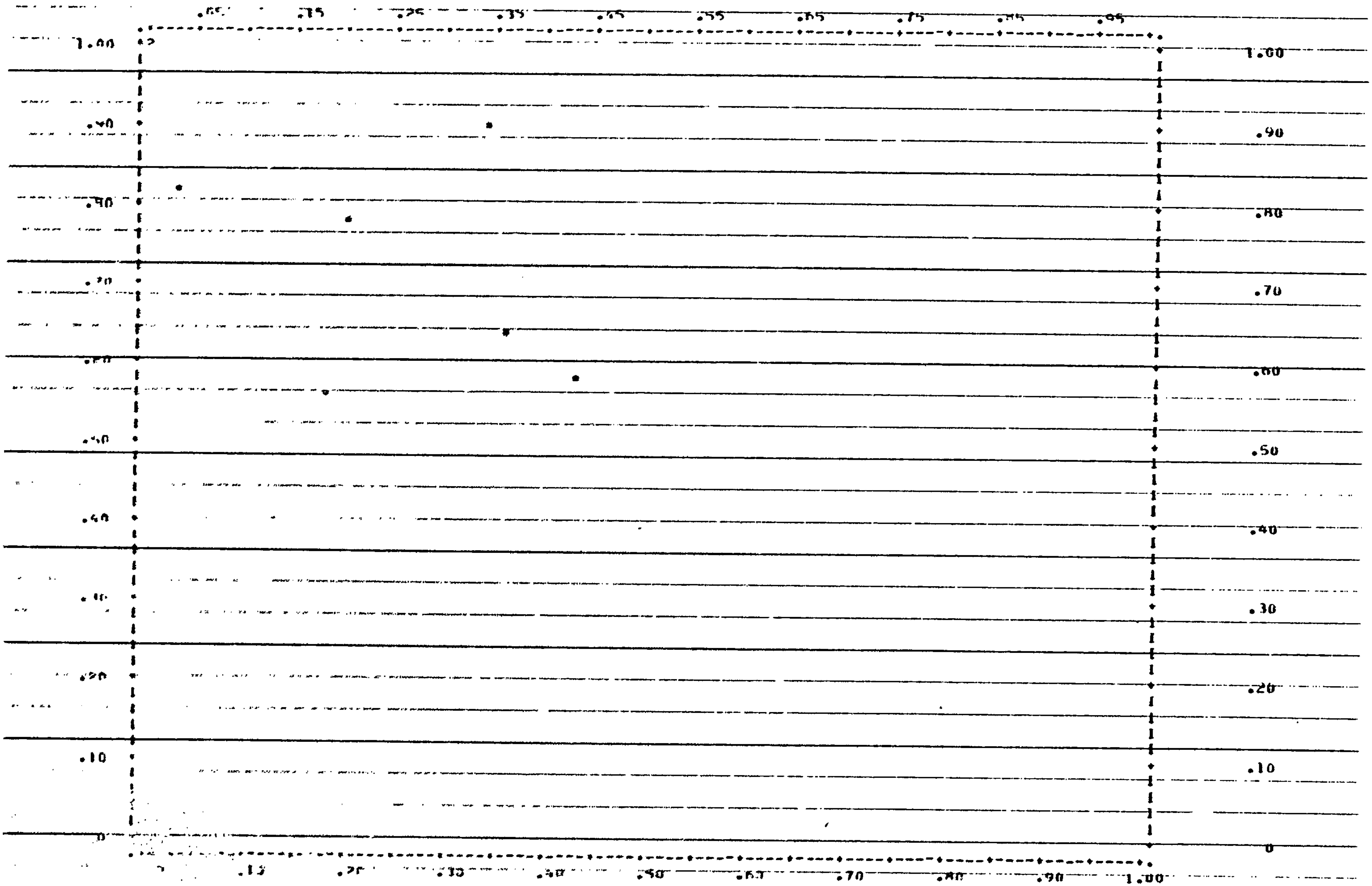
FILE SPSIDUO (CREATION DATE = [illegible])
SCATTERGRAM OF (DOWN) [illegible] (ACROSS) DENSITY

06/05/77. 14.2[illegible]. PAGE 2



PAGE 2



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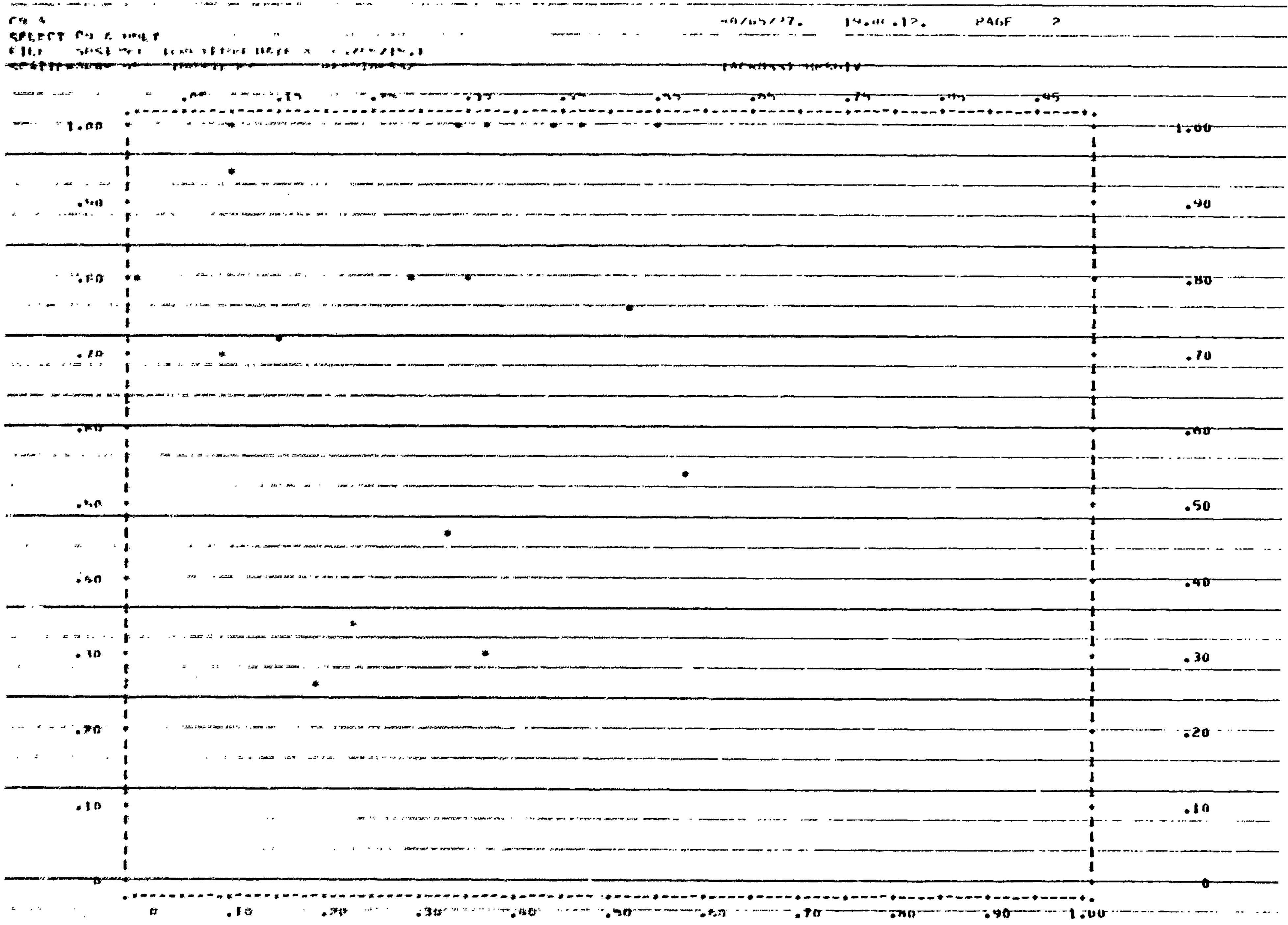
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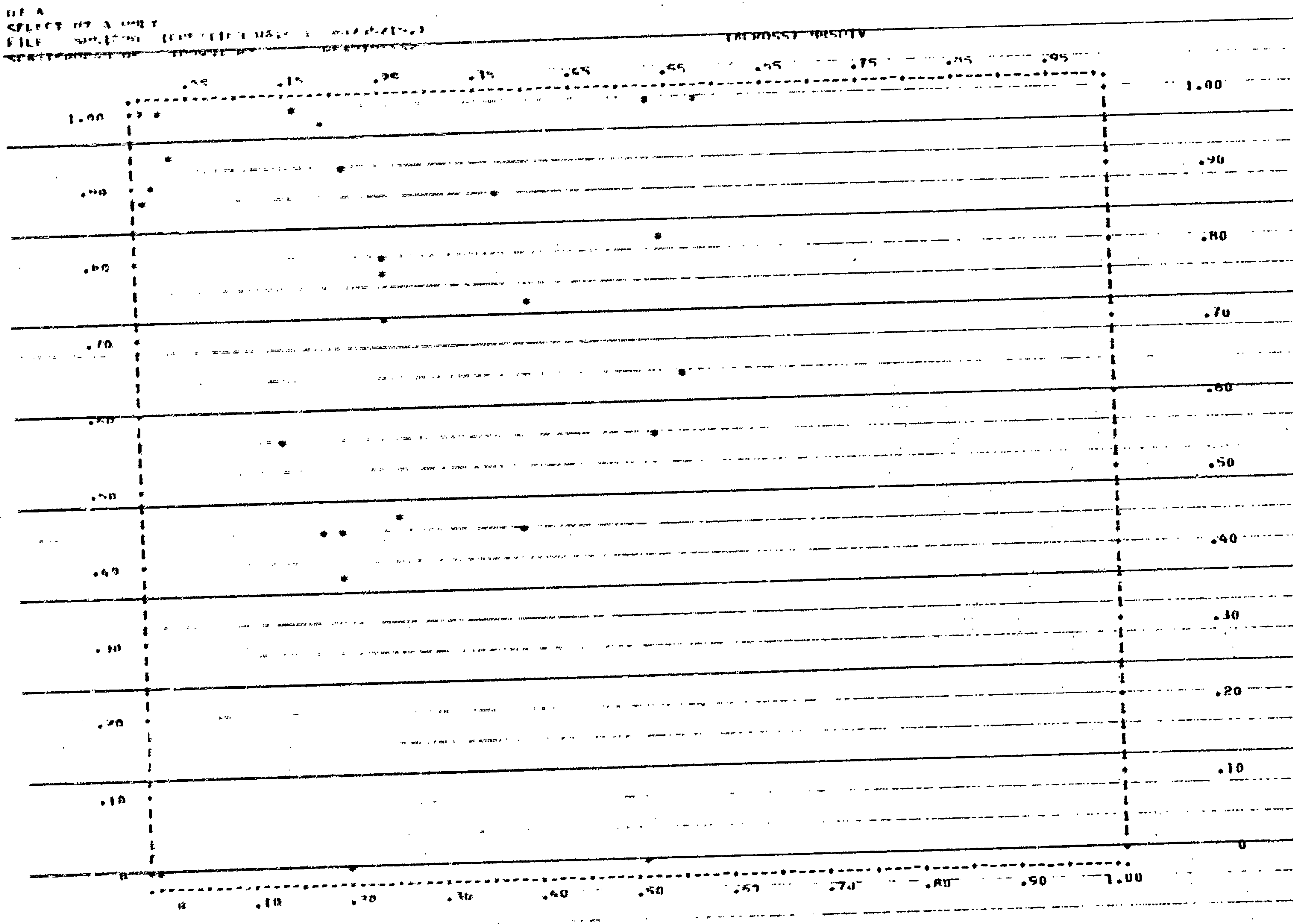
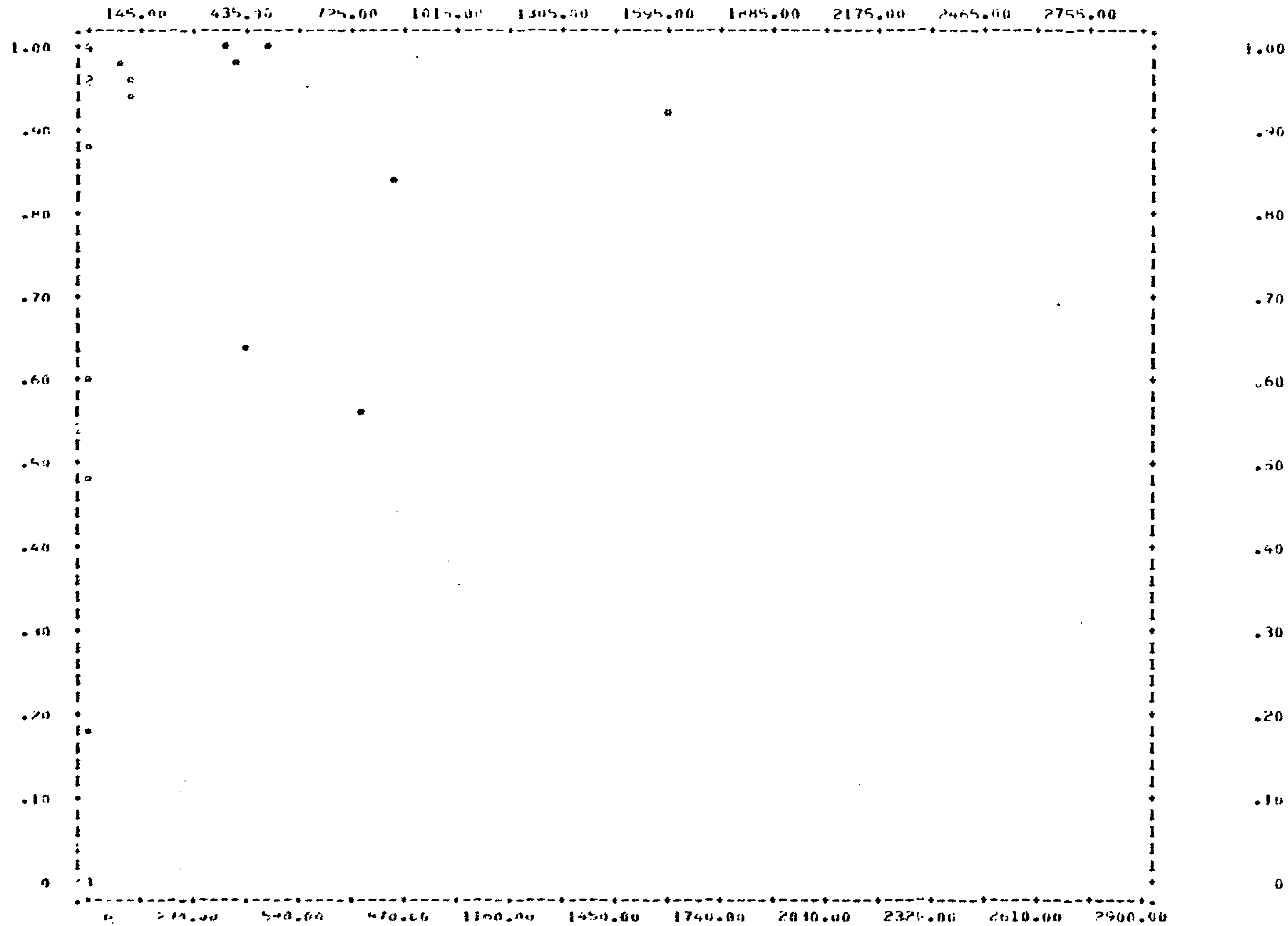
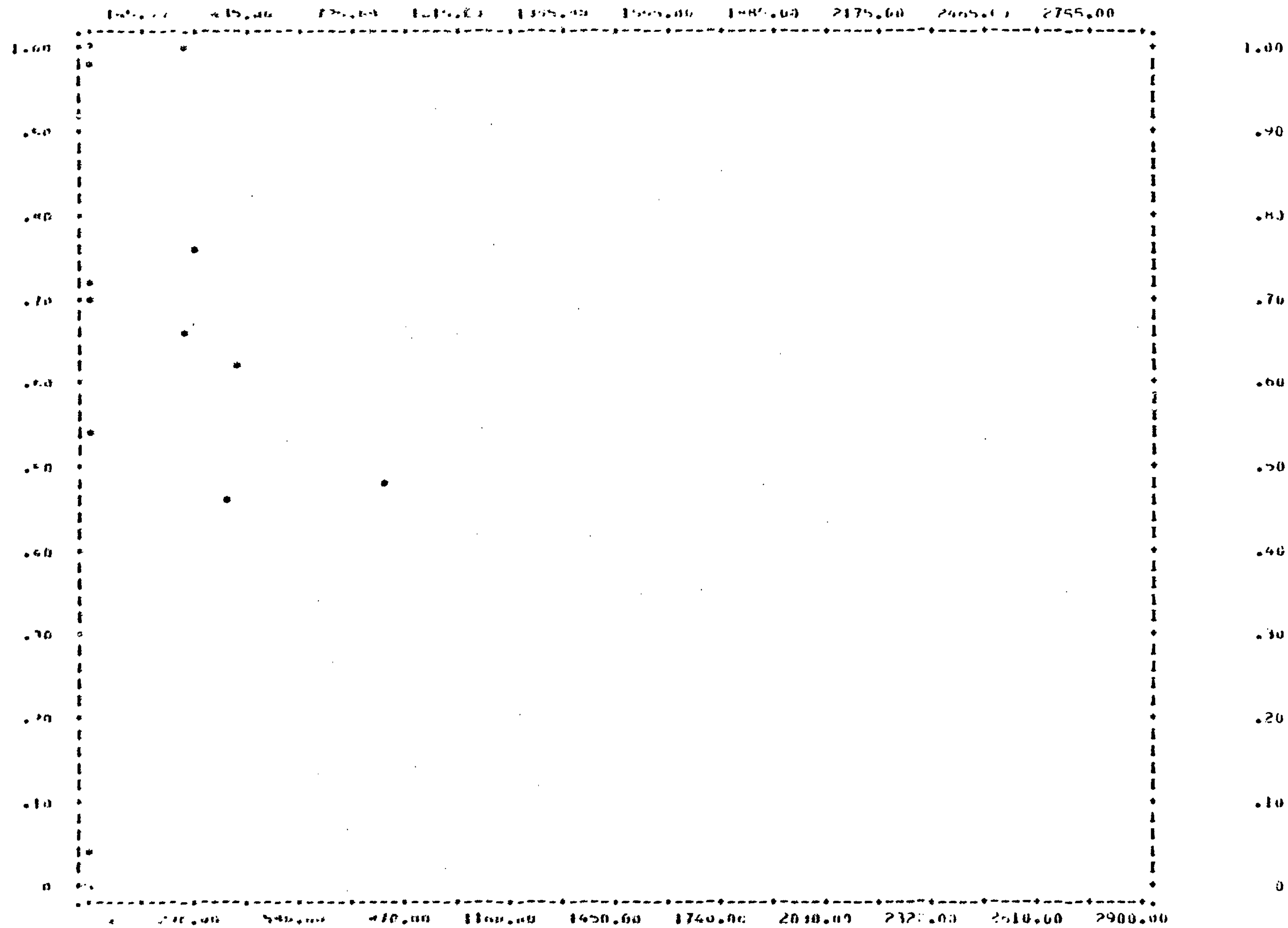


A7 V 80/05/21. 17.47.01. PAGE 2
SELECT A7 V ONLY
FILE SESI??? (CREATION DATE = 80/05/15.)
SCATTERGRAM OF (DOWN) R1 REV[illegible] (ACROSS) TWP TIME WAITING PARTS



PAGE 2

(ACROSS) TWO   TIME WAITING PARTS



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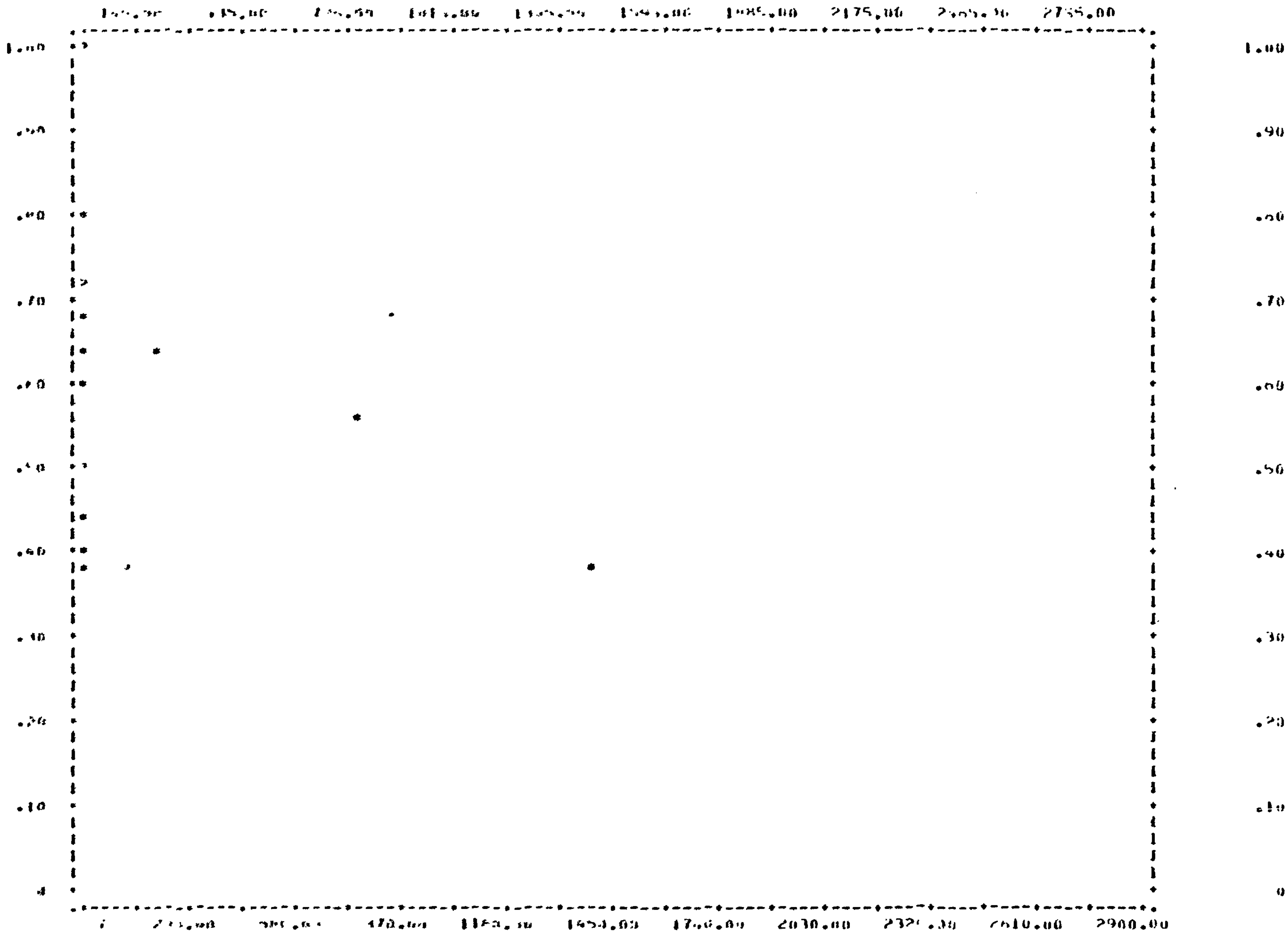
SELECT CITY ONLY

PAGE

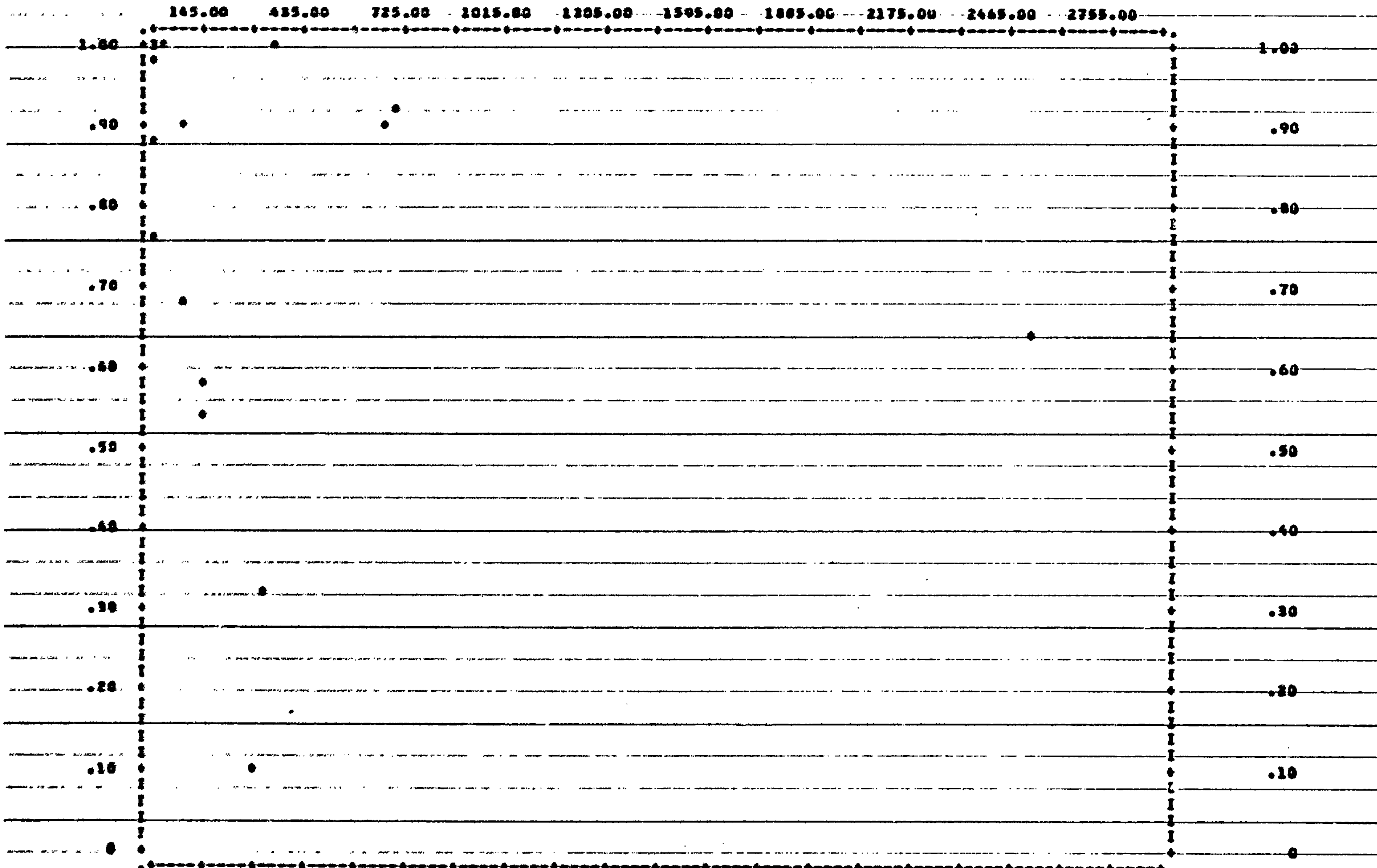
(ACROSS)



A13V
SELECT A13V ONLY
FILE SPSIP90 (CREATION DATE = 80/05/15.)

80/05/28. 23.12.42. PAGE 2

SCATTERGRAM OF (DOWN) R2 READINESS2
(ACROSS) TWP TIME WAITING PARTS



85 V
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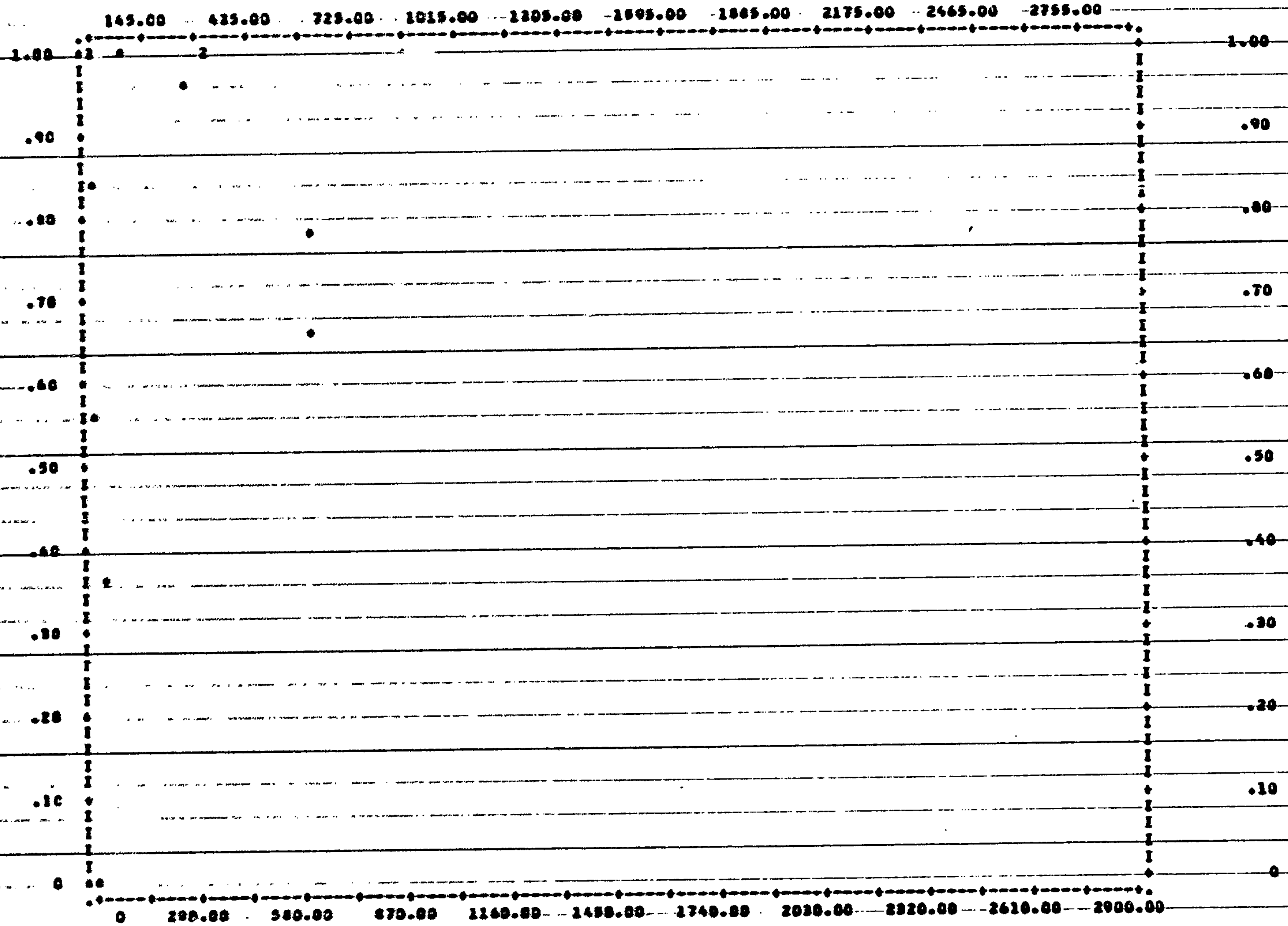
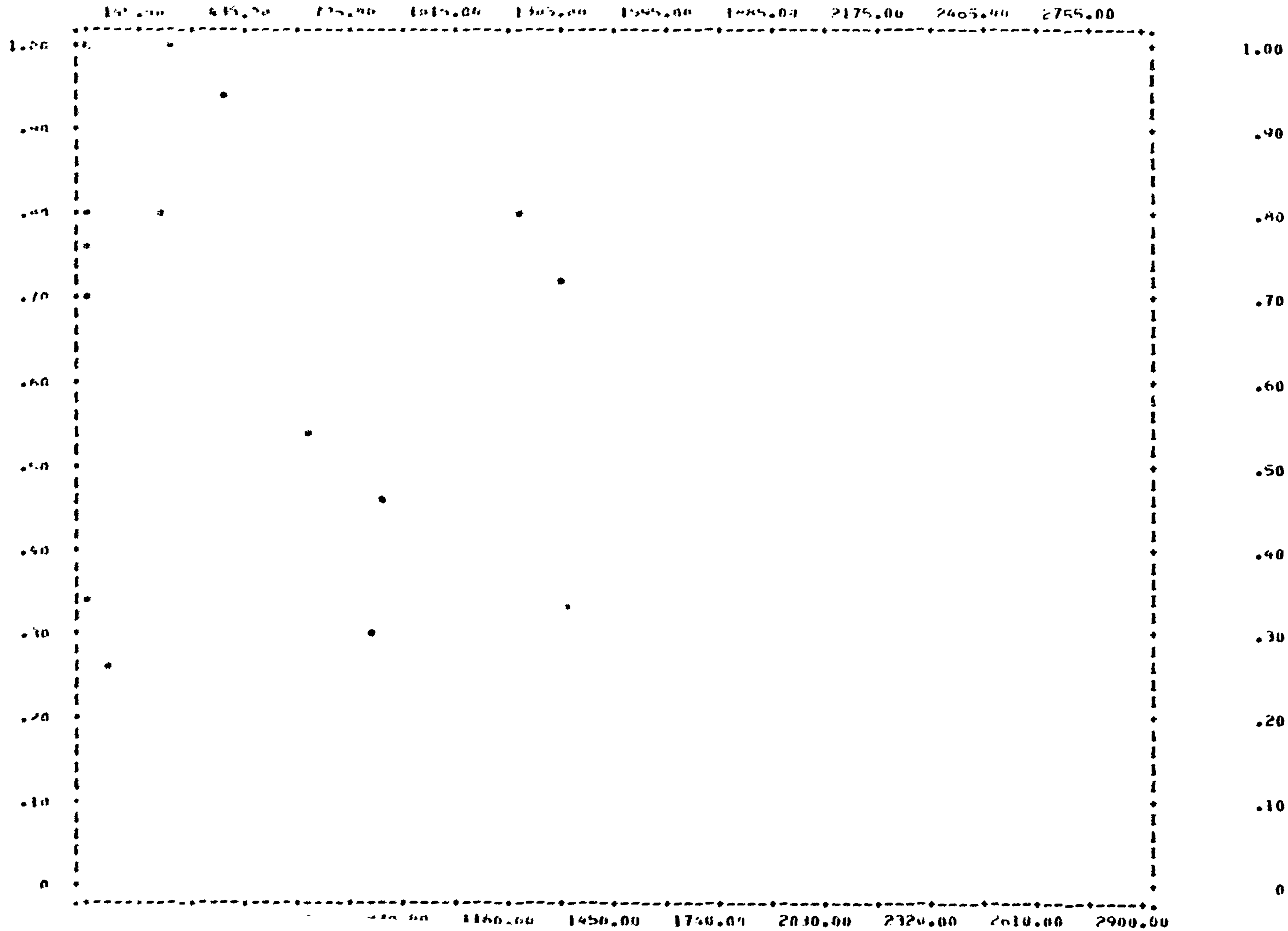
FILE SPSIP90 (CREATION DATE = 80/05/15.)

SCATTERGRAM OF (DOWN) R2 READINESS2
(ACROSS) TWP TIME WAITING PARTS



PAGE 2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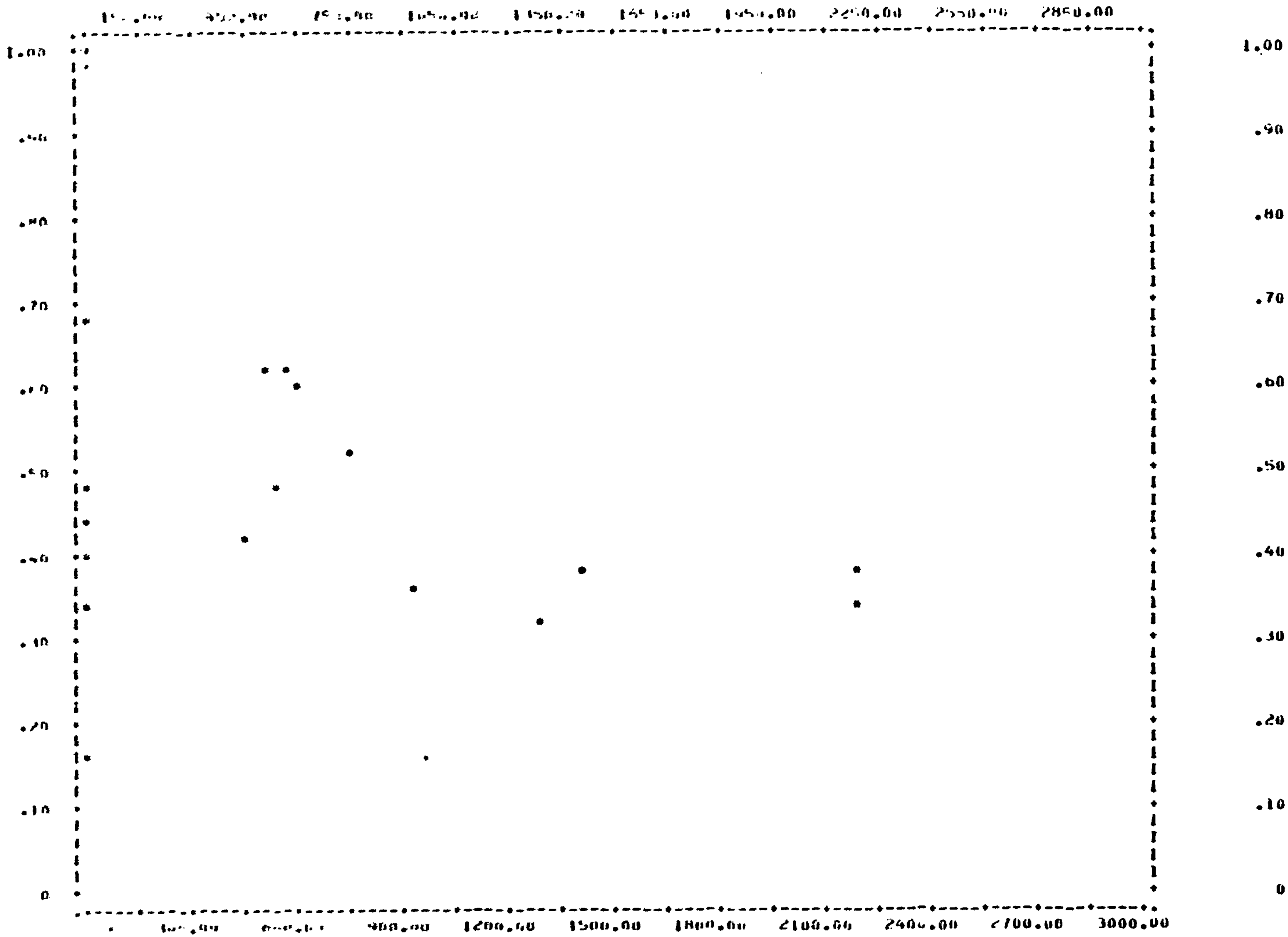
SELECT A1 & ONLY

SCATTERGRAM OF

PAGE 2

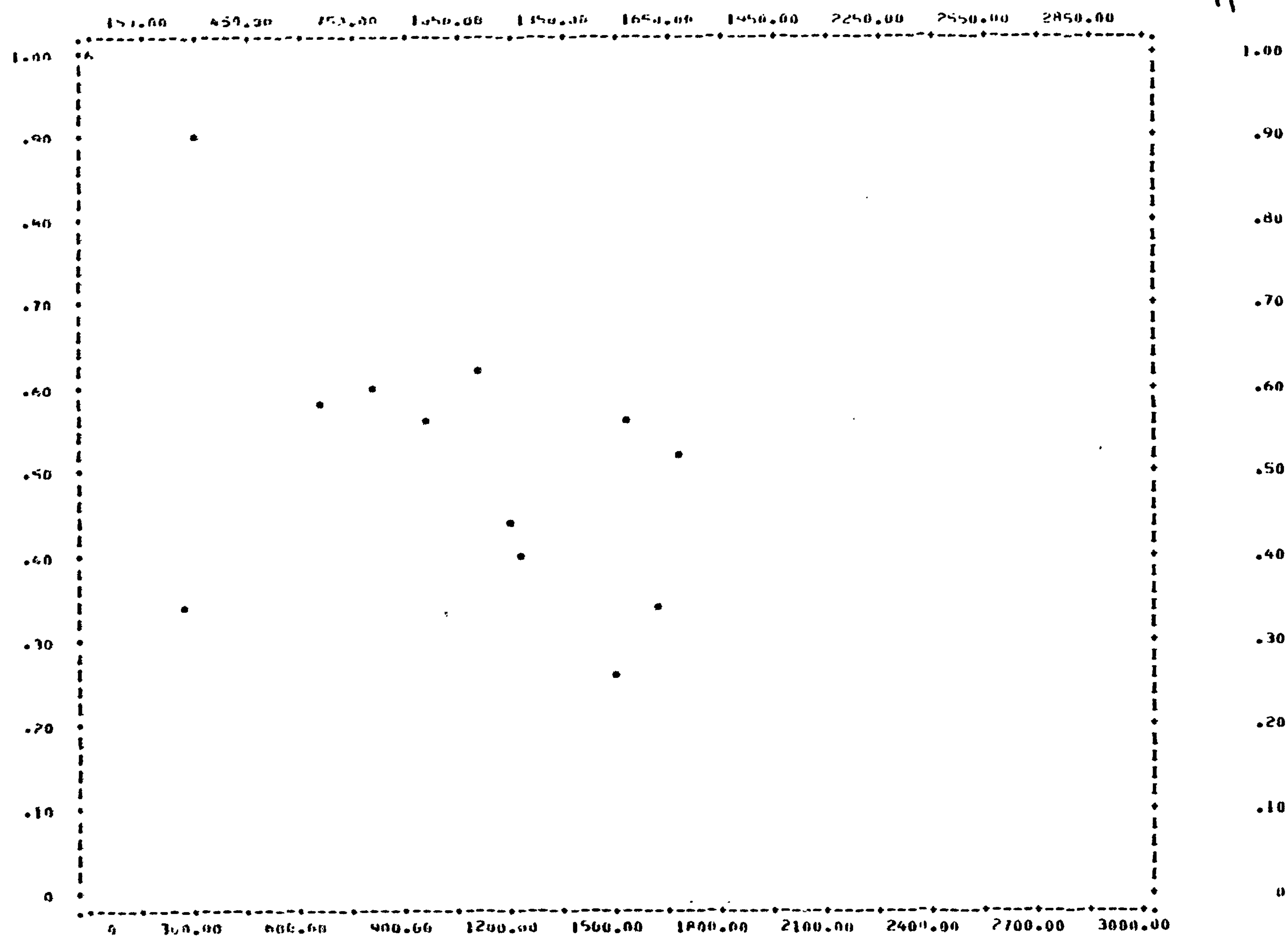
(ACROSS) SOWNTIME SUPPLY DOWN TIME



ALIA
SELECT ALIA ONLY
FILE SPS1P90 (CREATION DATE = 80/05/15.)
SCATTERGRAM OF (DOWN) RI READINESS

80/05/21. 17.1?.36. PAGE 2

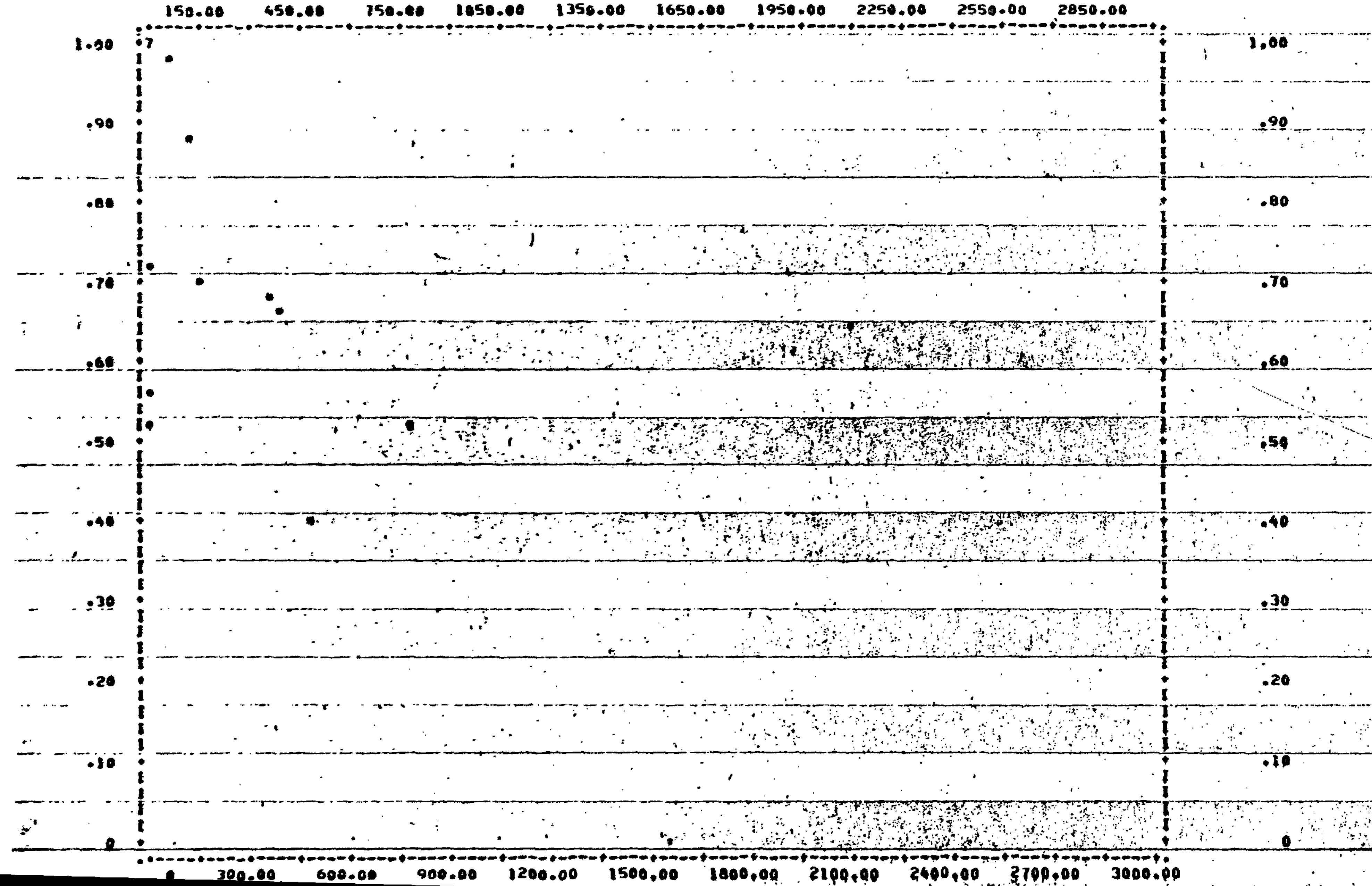
(ACROSS) SOWNTIME SUPPLY DOWN TIME



CS A
SELECT CS A ONLY
FILE SPSIP90 (CREATION DATE = 80/05/15.)

80/05/30. 14.34.46. PAGE 2

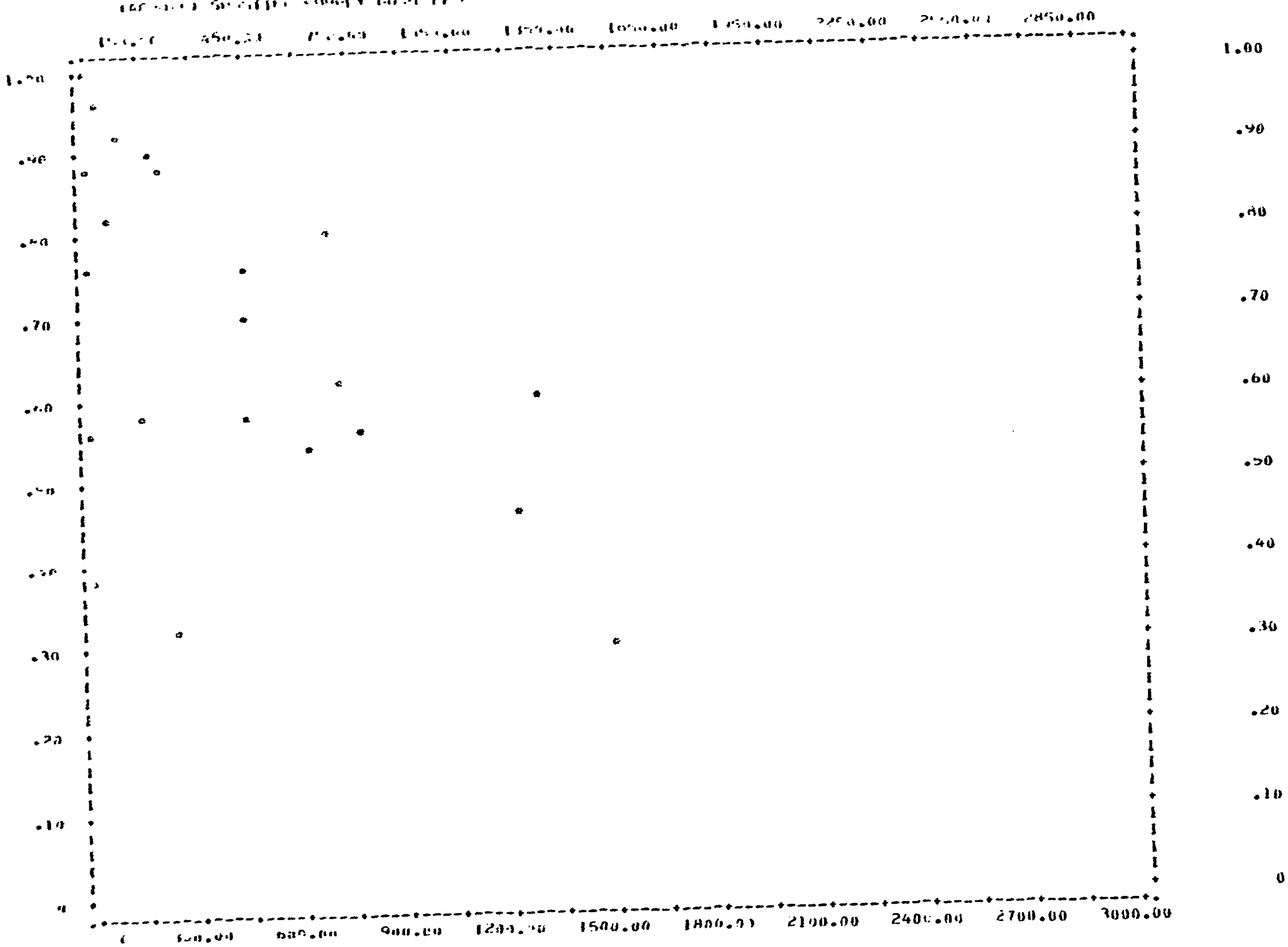
SCATTERGRAM OF (DOWN) R1 READINESS1
(ACROSS) SDWNTIME SUPPLY DOWN TIME

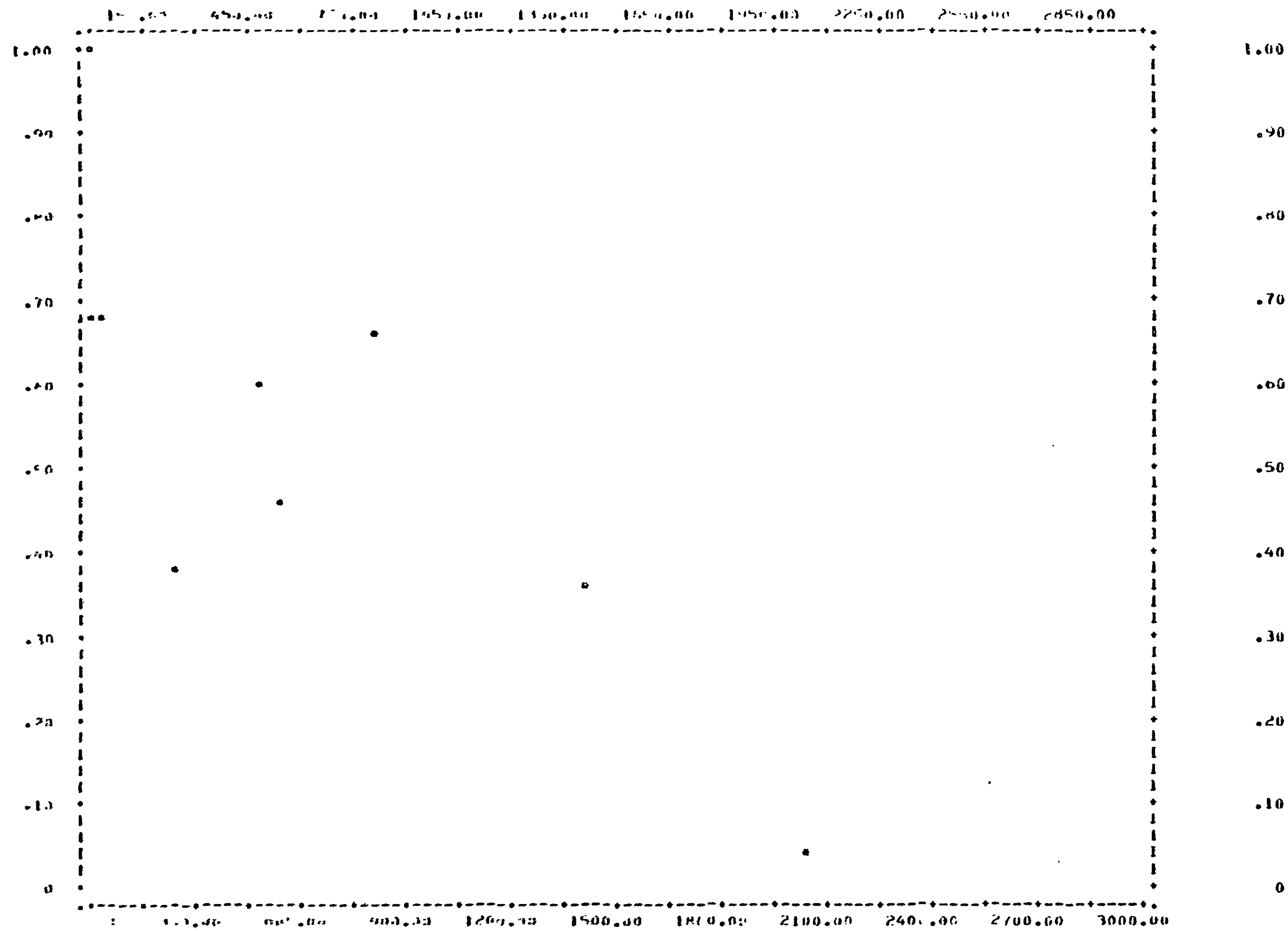


PAGE 2

SELECT [illegible]
FILE [illegible]

SCATTERGRAM OF [illegible]





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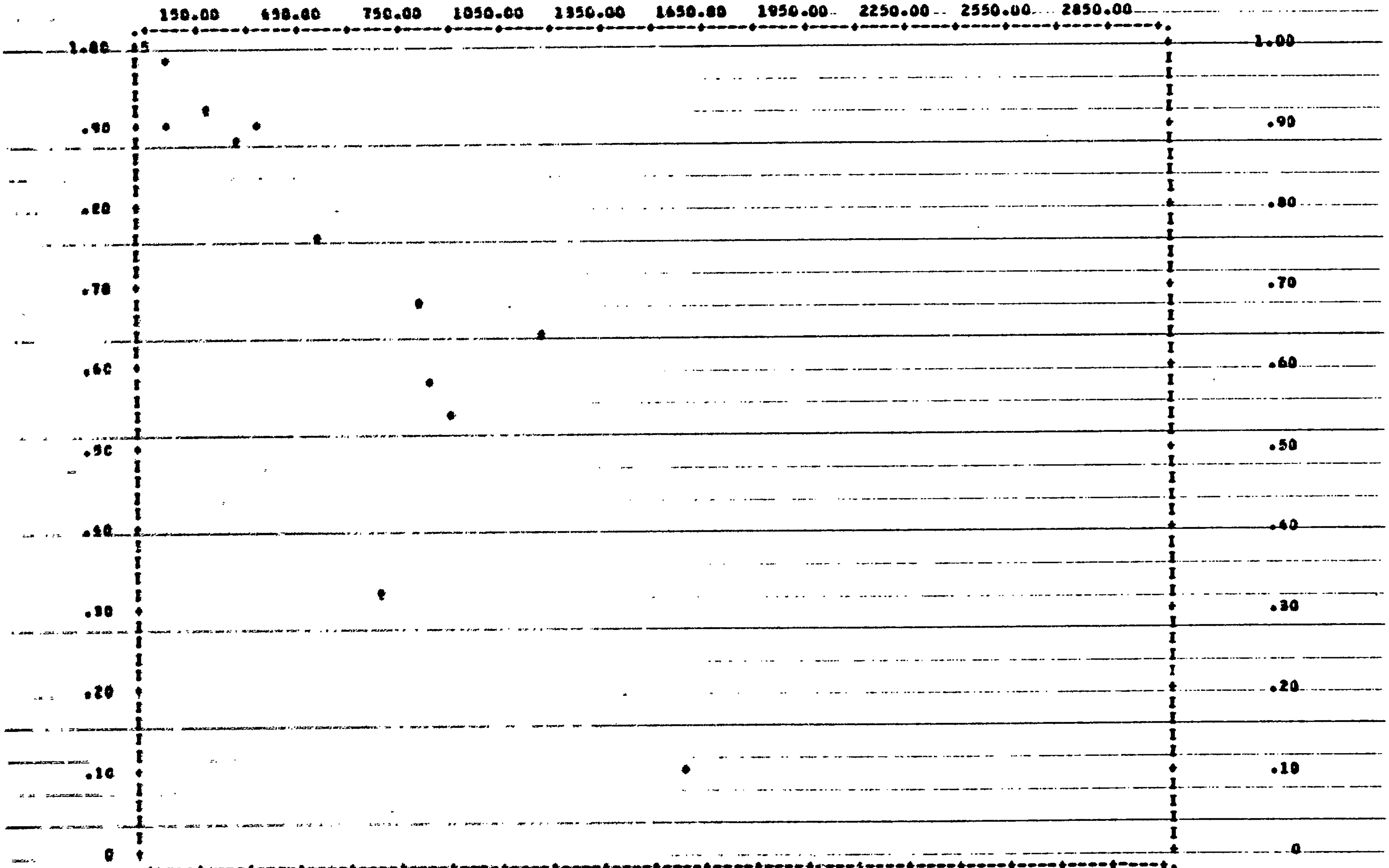
A13V 80/05/28. 22.23.56. PAGE 2
SELECT A13V ONLY
FILE SPSIP90 (CREATION DATE = 80/05/15.)

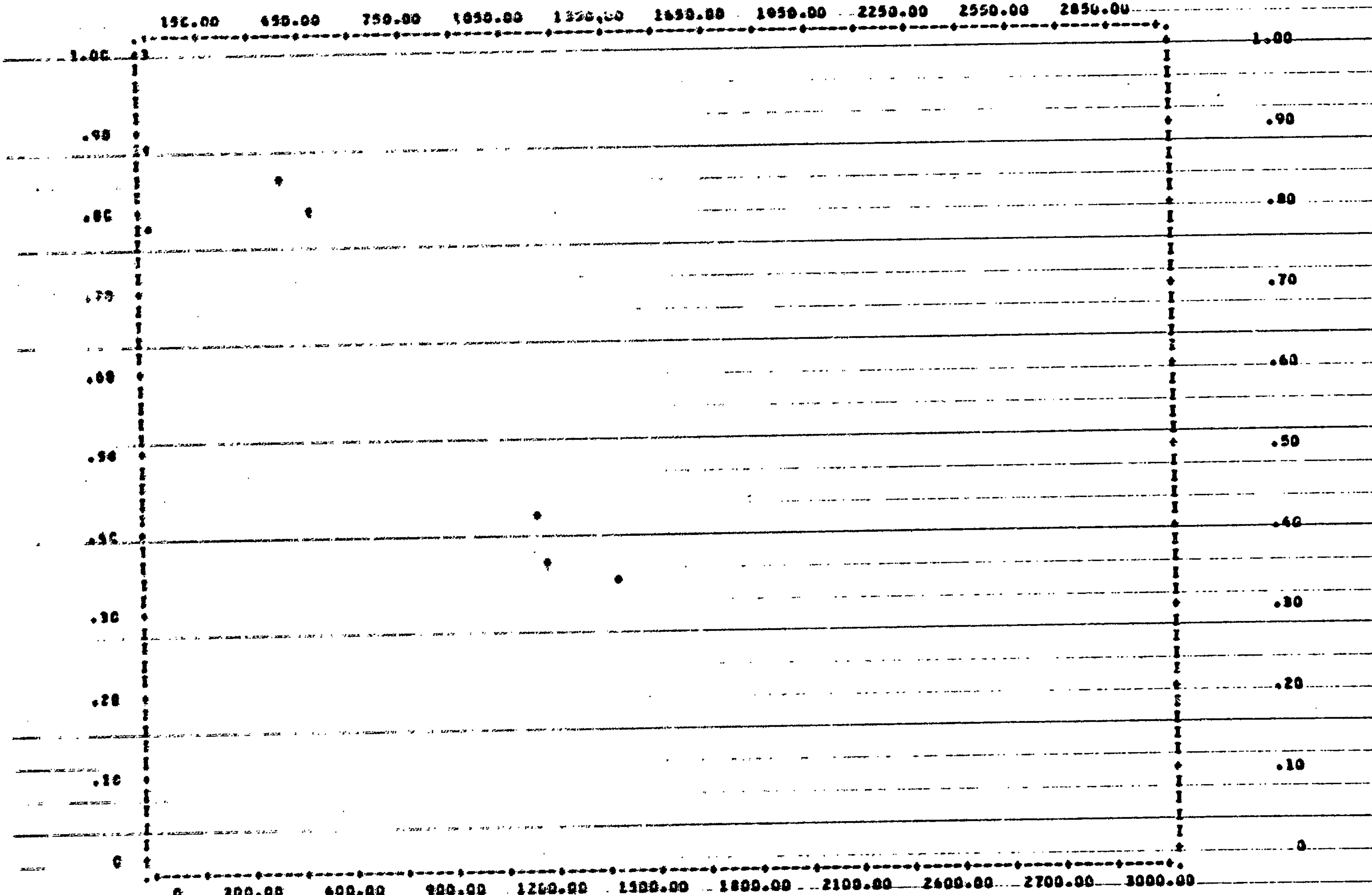
SCATTERGRAM OF (DOWN) R2 READINESS2
(ACROSS) SDNTIME SUPPLY DOWN TIME



80/05/28. 22.24.31. PAGE 2

C3 V
SELECT C3 V ONLY
FILE SPS1P90 (CREATION DATE = 80/05/15.)

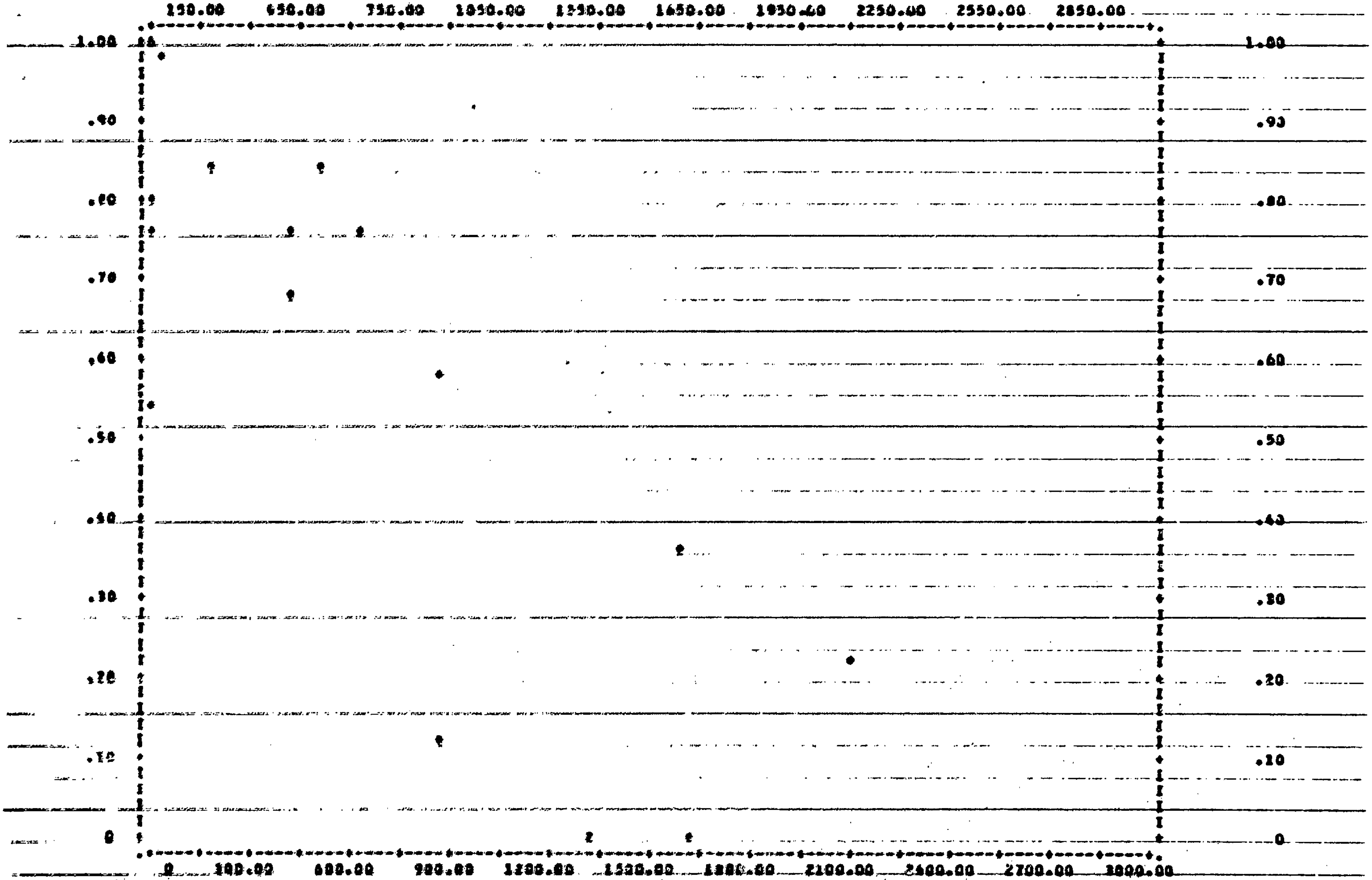
SCATTERGRAM OF (DOWN) #2 READINESS2
(ACROSS) SDOWNTIME SUPPLY DOWN TIME



DS A
SELECT DS A ONLY
FILE SPSIP90 (CREATION DATE = 80/05/15.)

80/05/28. 22.24.38. PAGE 2

SCATTERGRAM OF (DOWN) #2 READINESS2
(ACROSS) SDWNTIME SUPPLY DOWN TIME

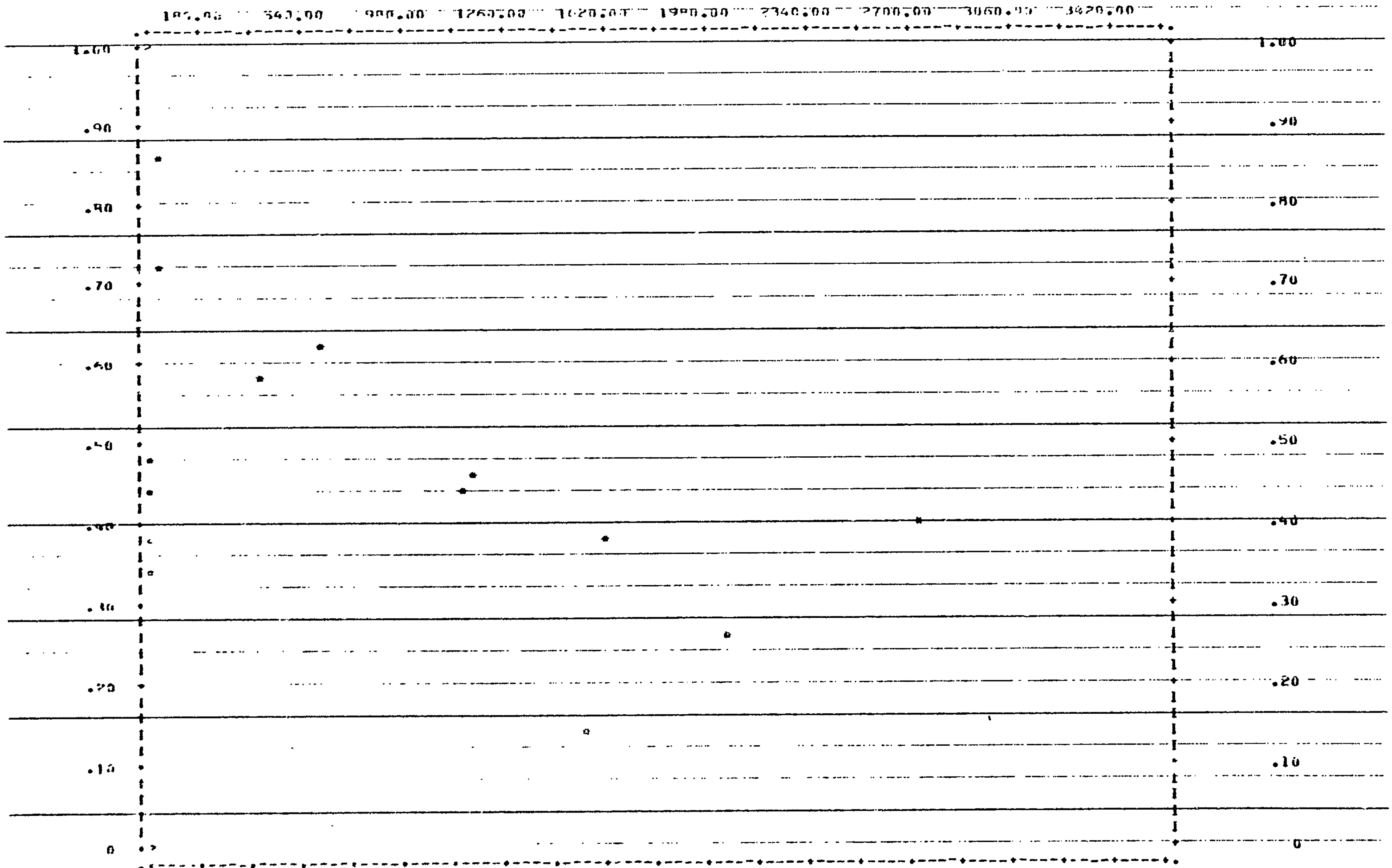


#9

A1 A
SELECT A1 A ONLY
FILE SPSI050 (CREATION DATE = 83/05/15.)

83/05/27. 20.47.33. PAGE 2

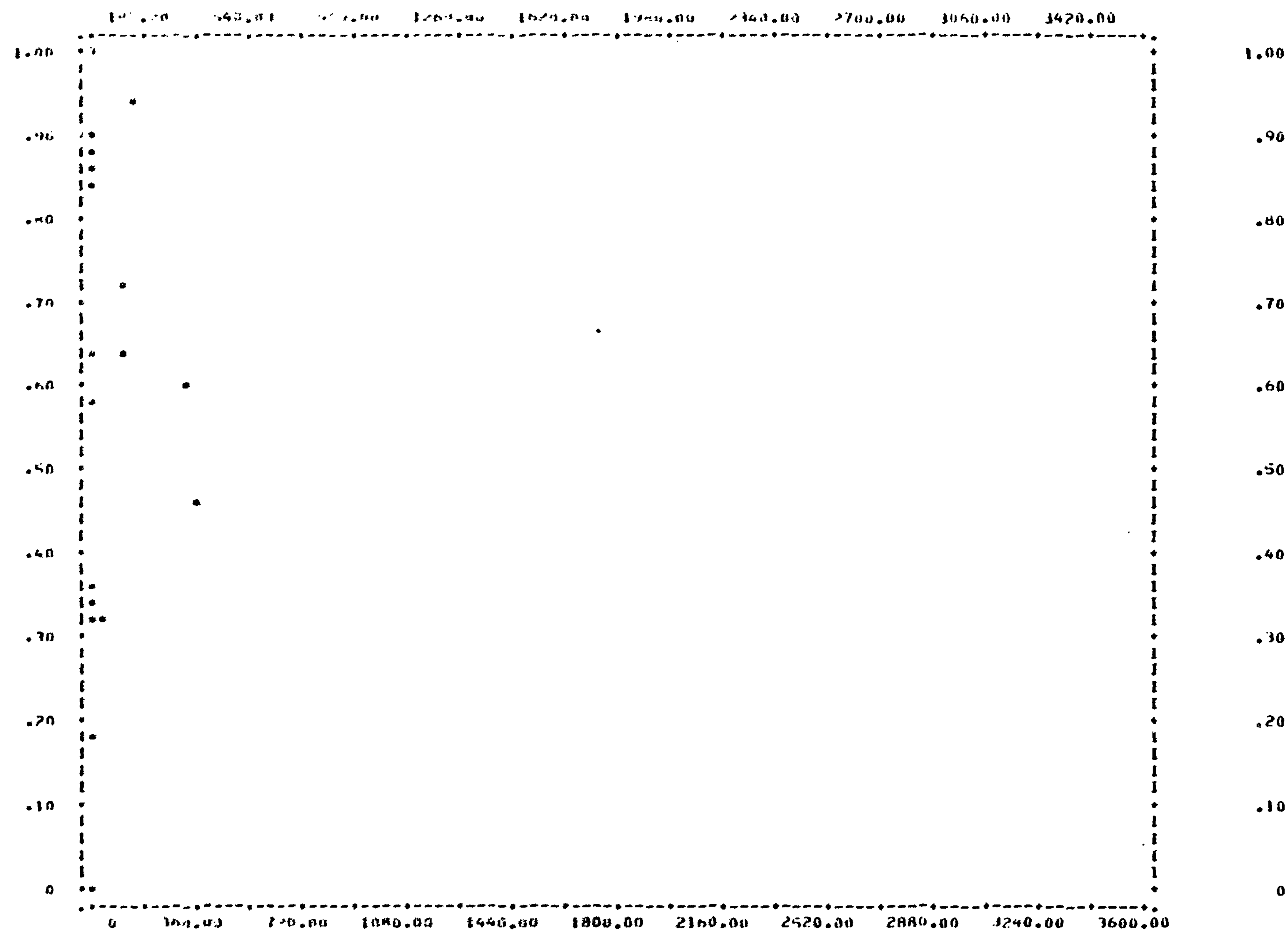
SCATTERGRAM OF (DOWN) R1 SEATINESS1
(ACROSS) MOUNTIME MAINTENANCE DOWN TIME



SELECT TO V ONLY

40/05/23. PAGE 2

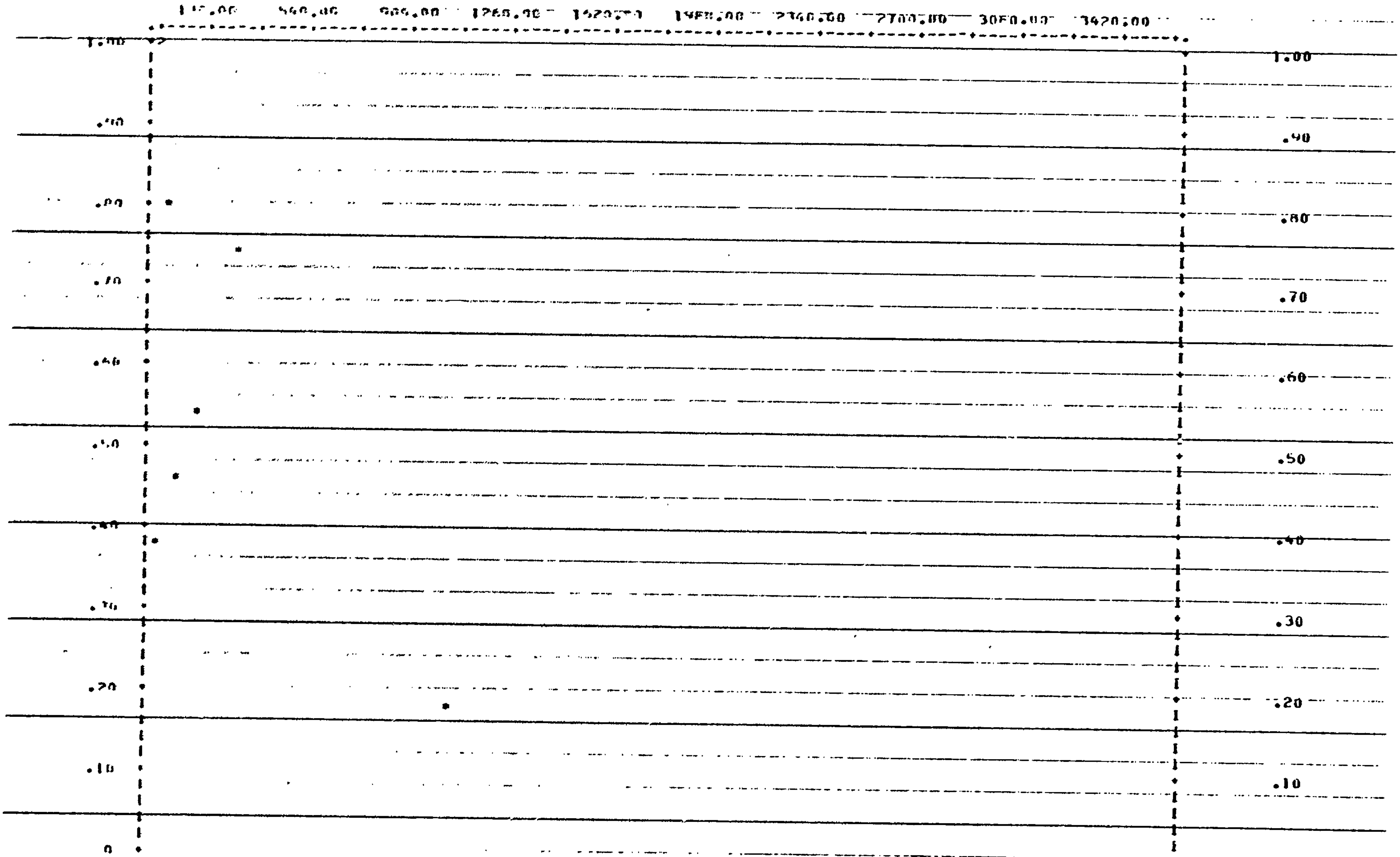
SCATTERGRAM OF (ACROSS) MAINTENANCE DOWN TIME

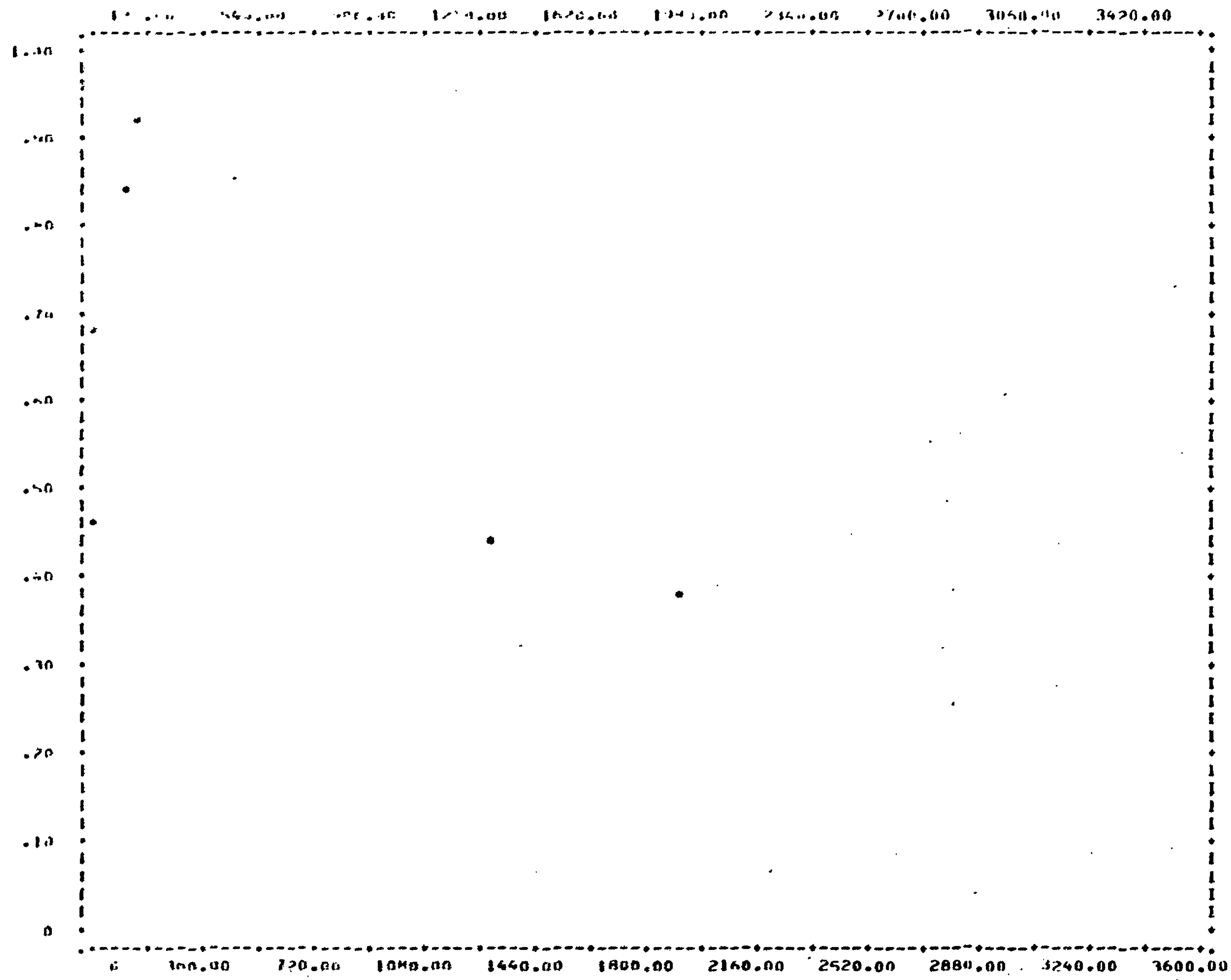


CG V
SELECT CG V ONLY
FILE [illegible] CREATION DATE = [illegible]

PAGE 2

SCATTERGRAM OF [illegible]

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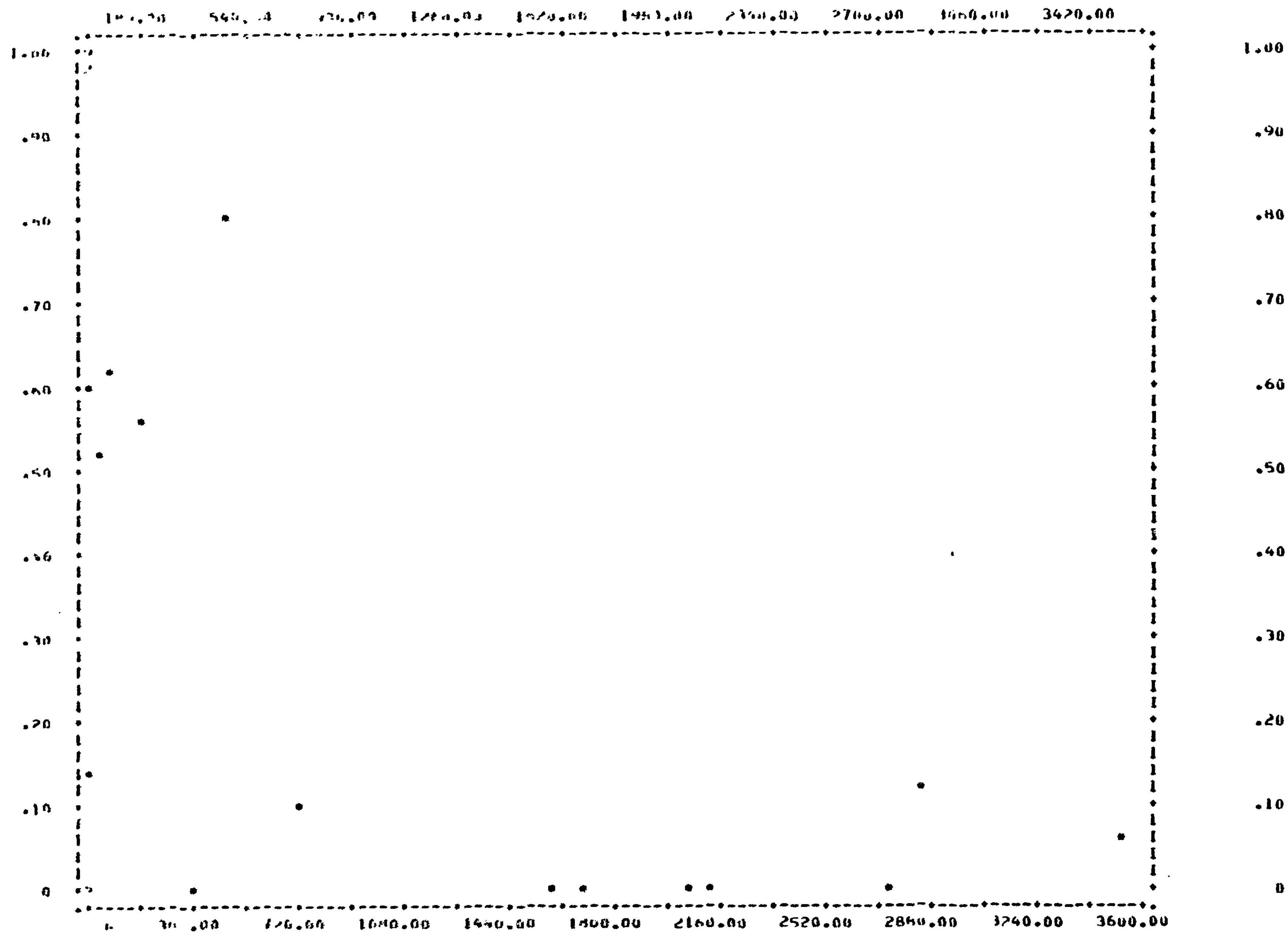
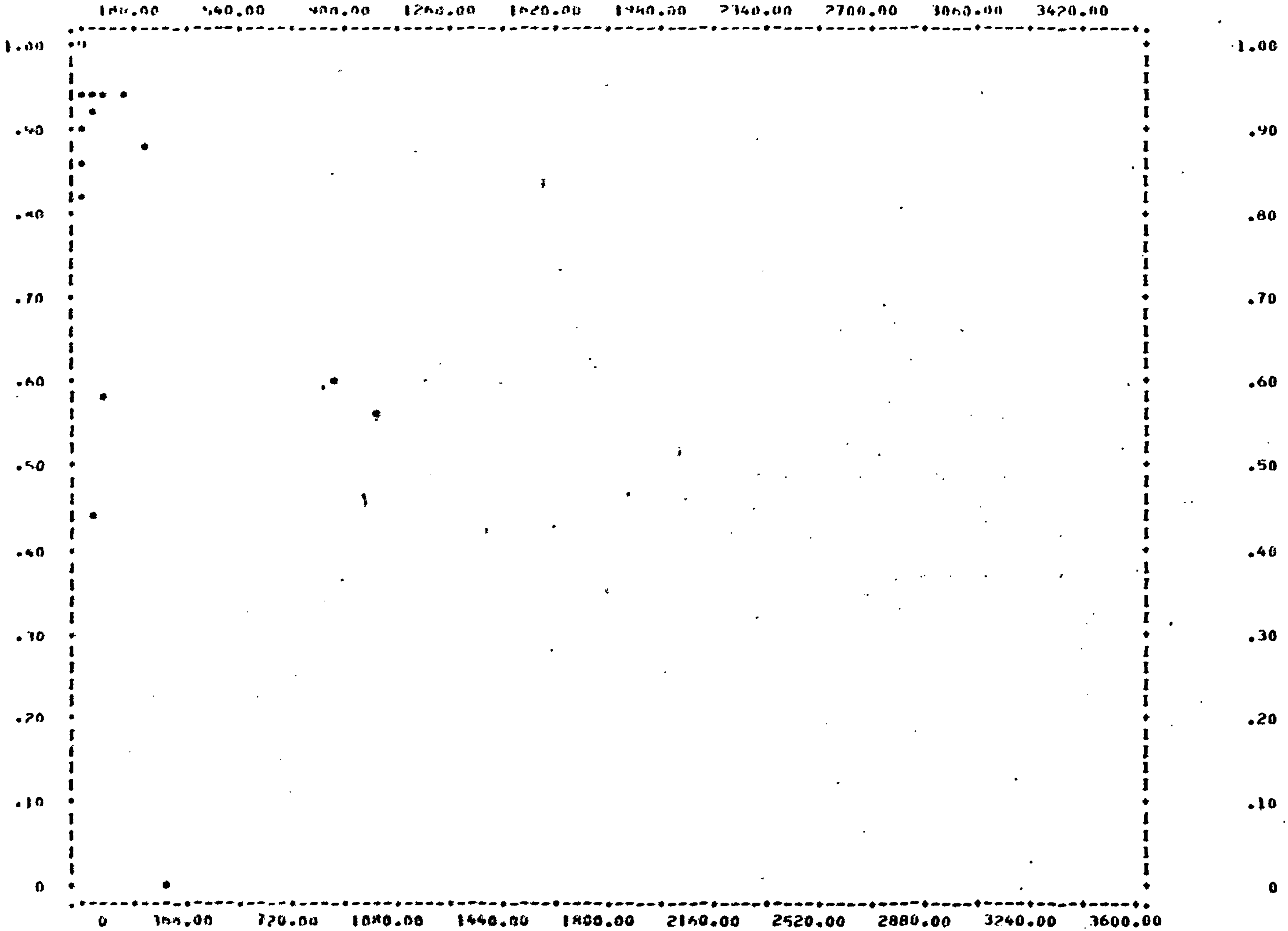
PAGE 2

(ACROSS) DOWNTIME MAINTENANCE DOWN TIME



SELECT HI V MULT
FILE SPS1093 (CREATION DATE = 06/05/75.)

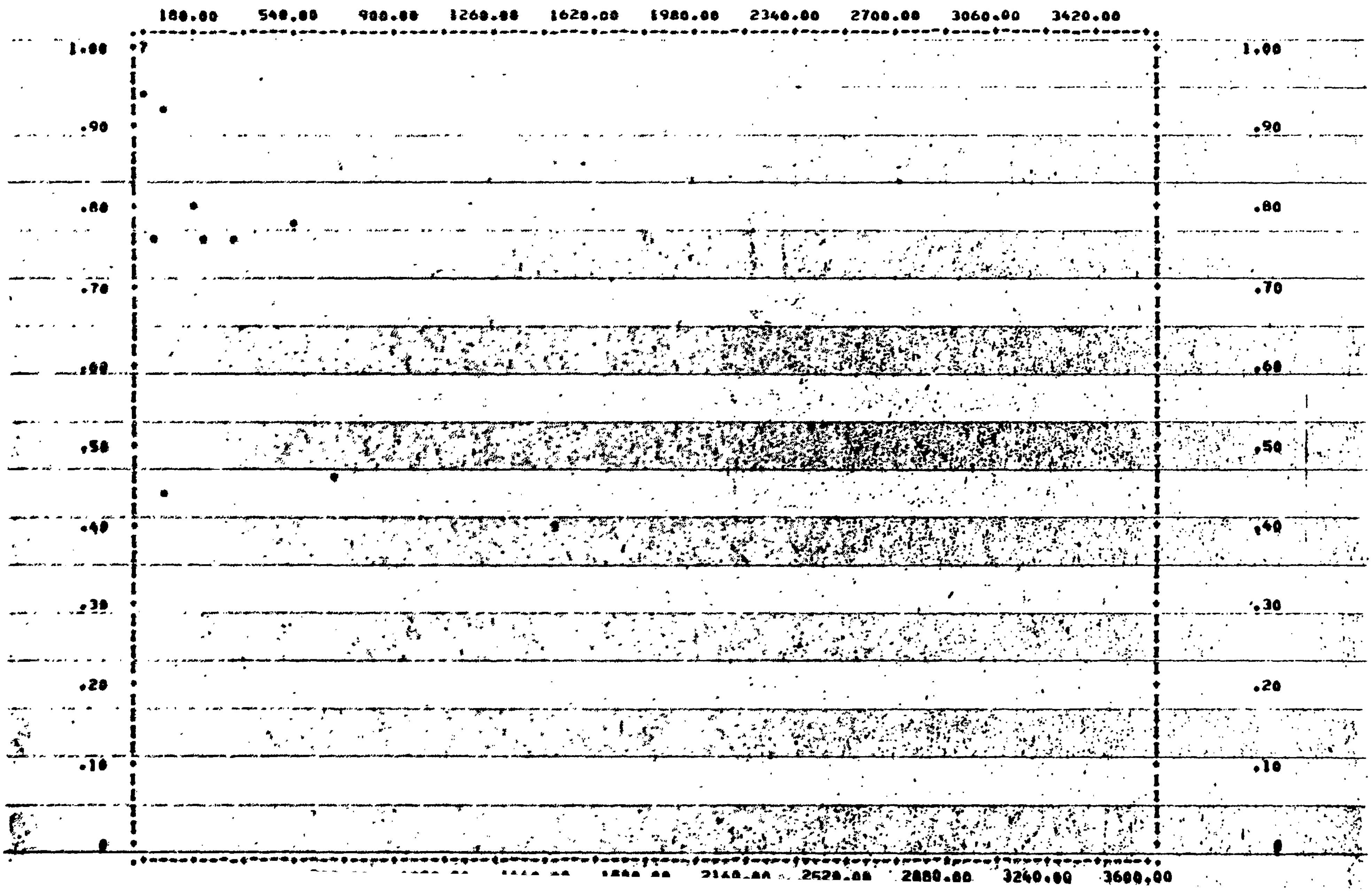
SCATTERGRAM OF (DOWN) R2 READINESS2
(ACROSS) MDWHITE MAINTENANCE DOWN TIME



CS A
SELECT CS A ONLY
FILE SPS1P90 (CREATION DATE = 80/05/15.)

80/05/30. 14.17.03. PAGE 2

SCATTERGRAM OF (DOWN) R2 READINESS2
(ACROSS) MDWNTIME MAINTENANCE DOWN TIME



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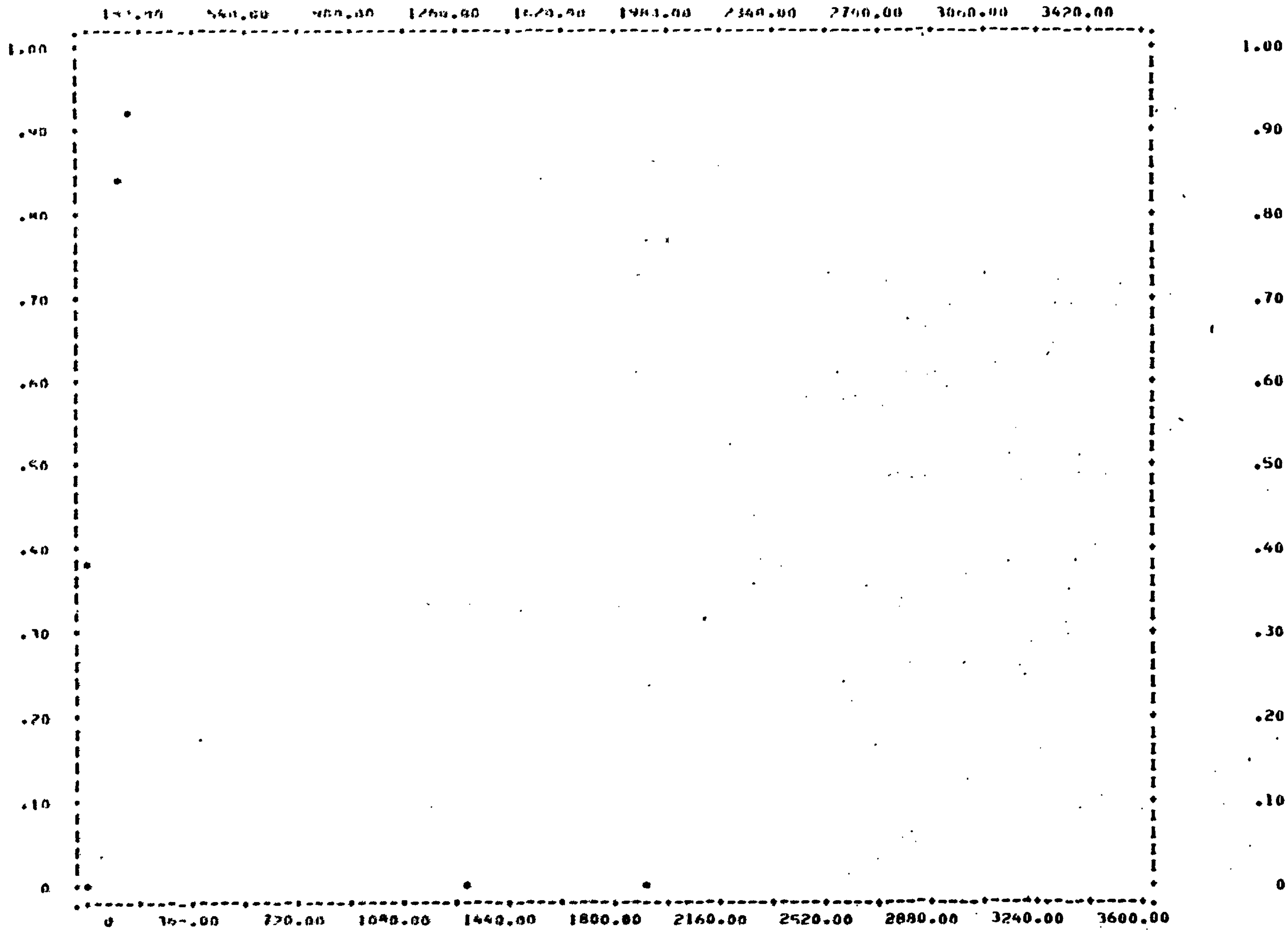
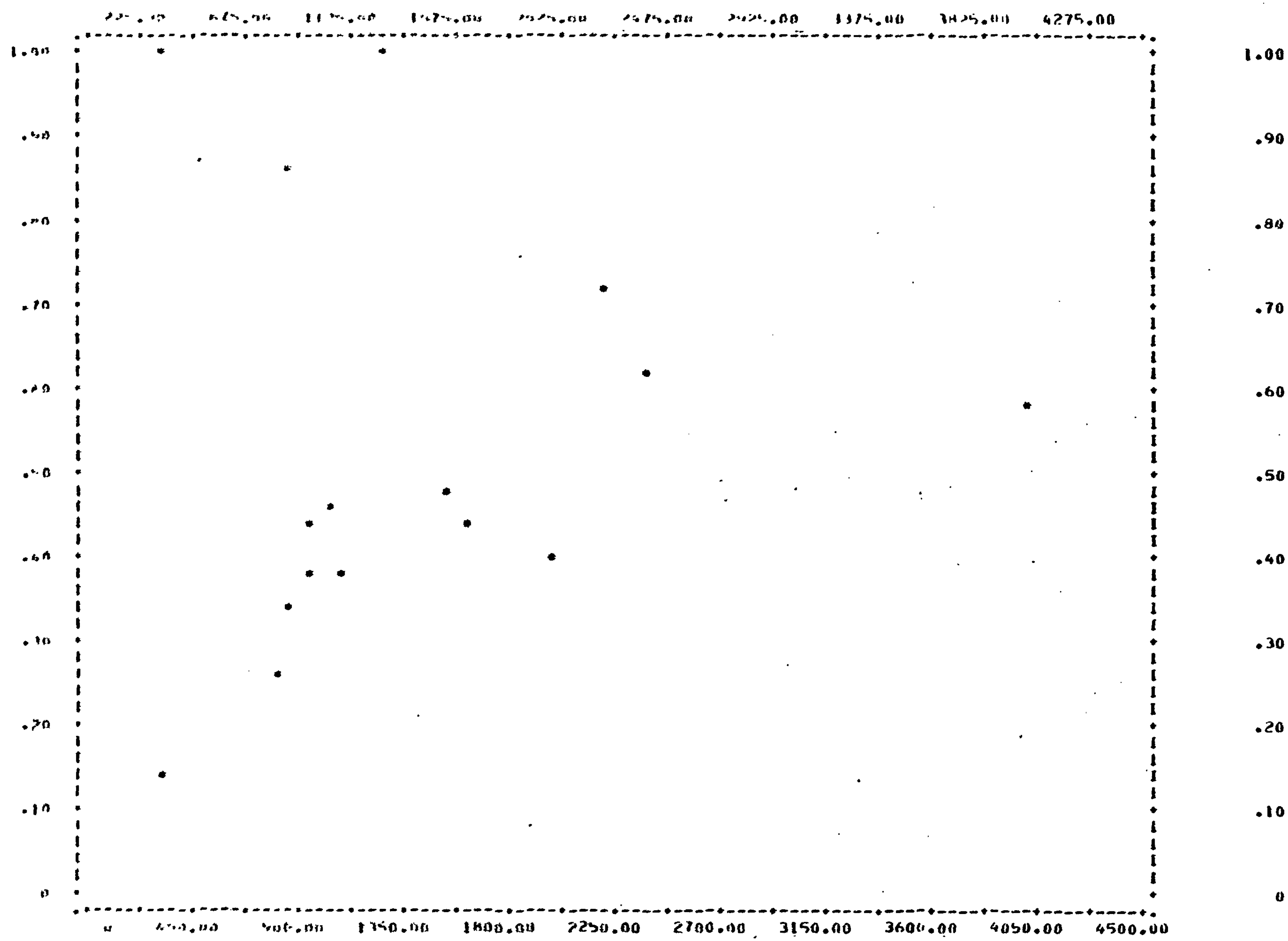
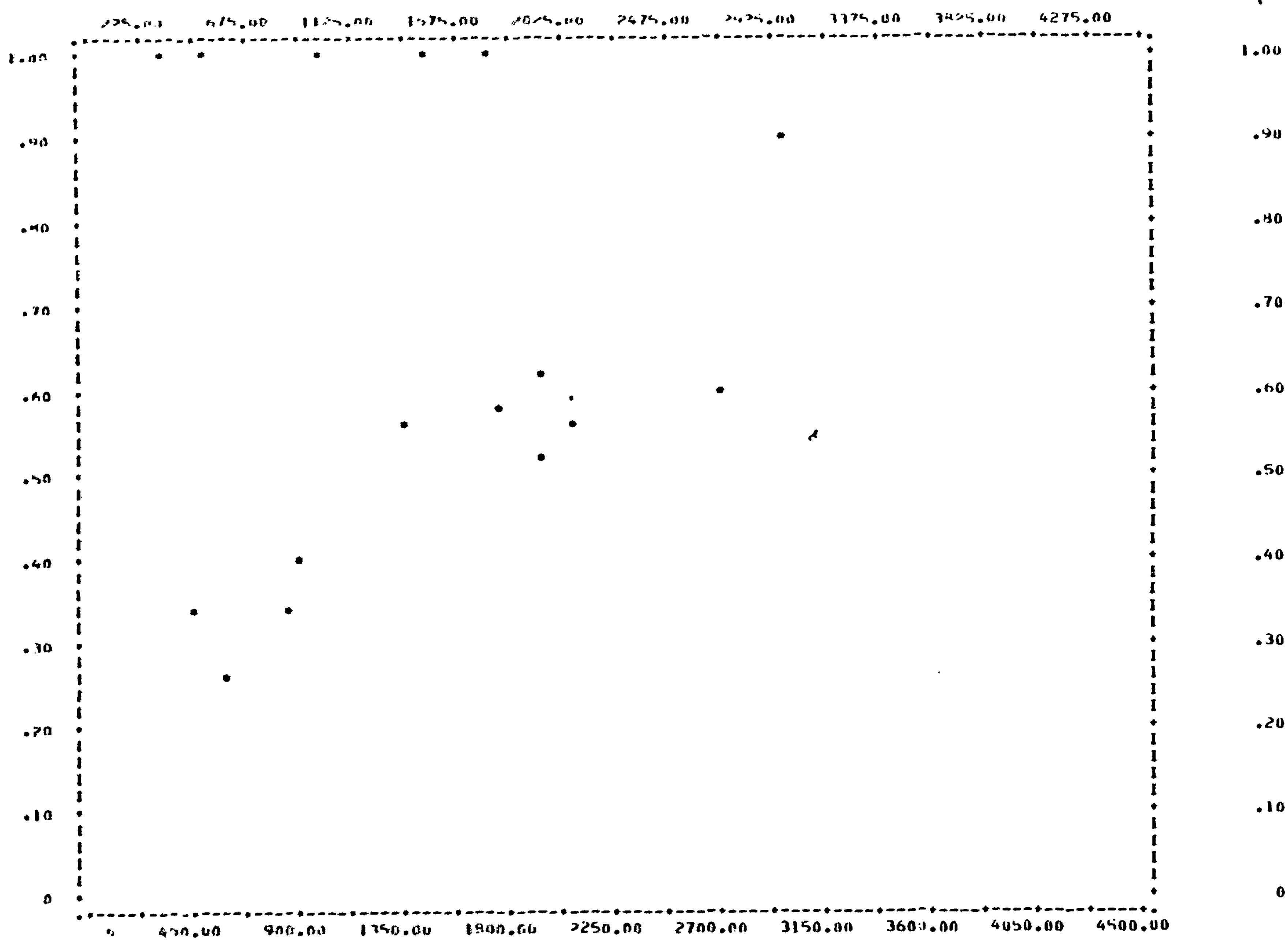


PAGE 2

SCATTERGRAM OF



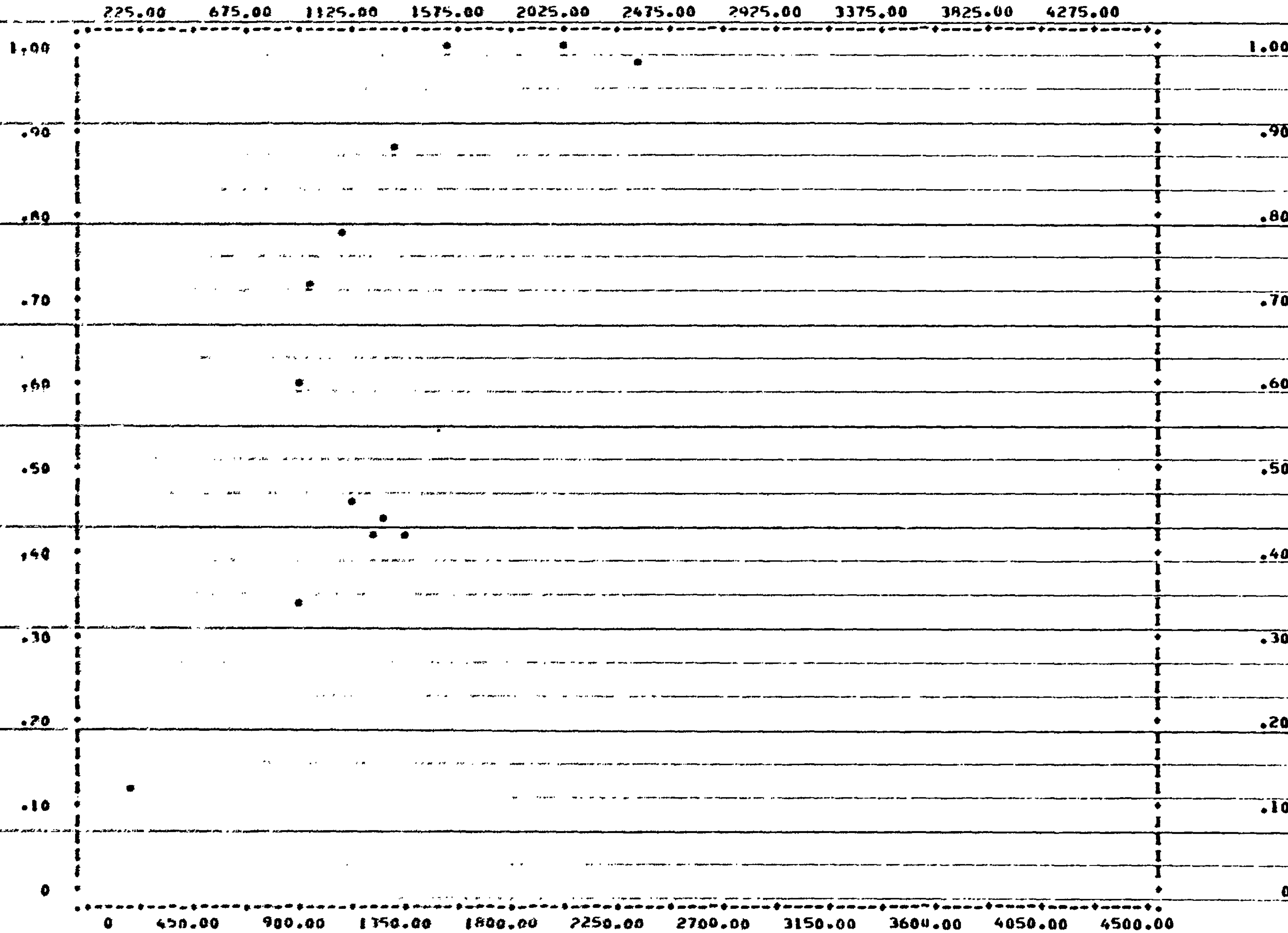
(ACROSS) OPTIME RADAR OPERATING HOURS



SELECT C3 A ONLY

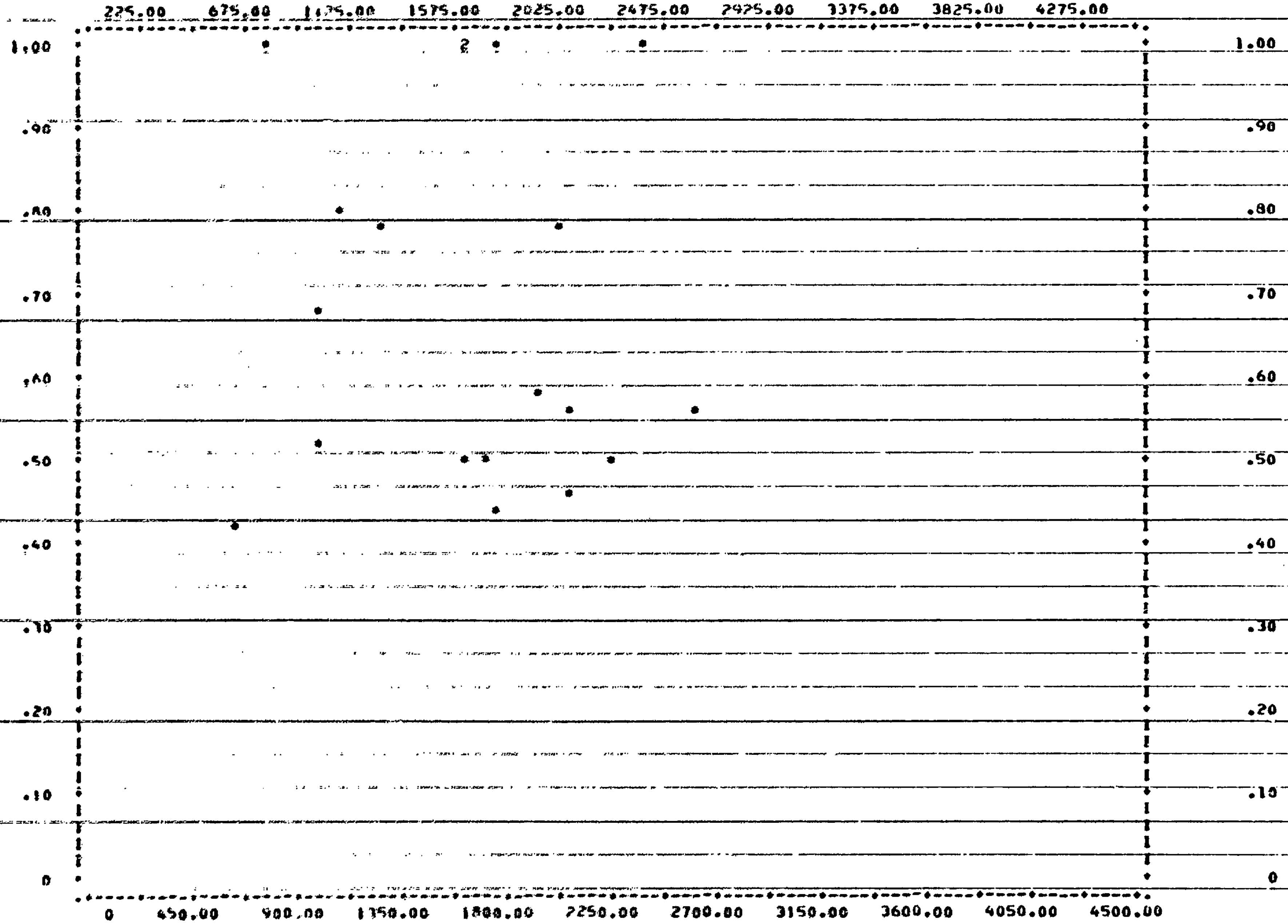
FILE SPSIP40 (CREATION DATE = 80/05/15.)

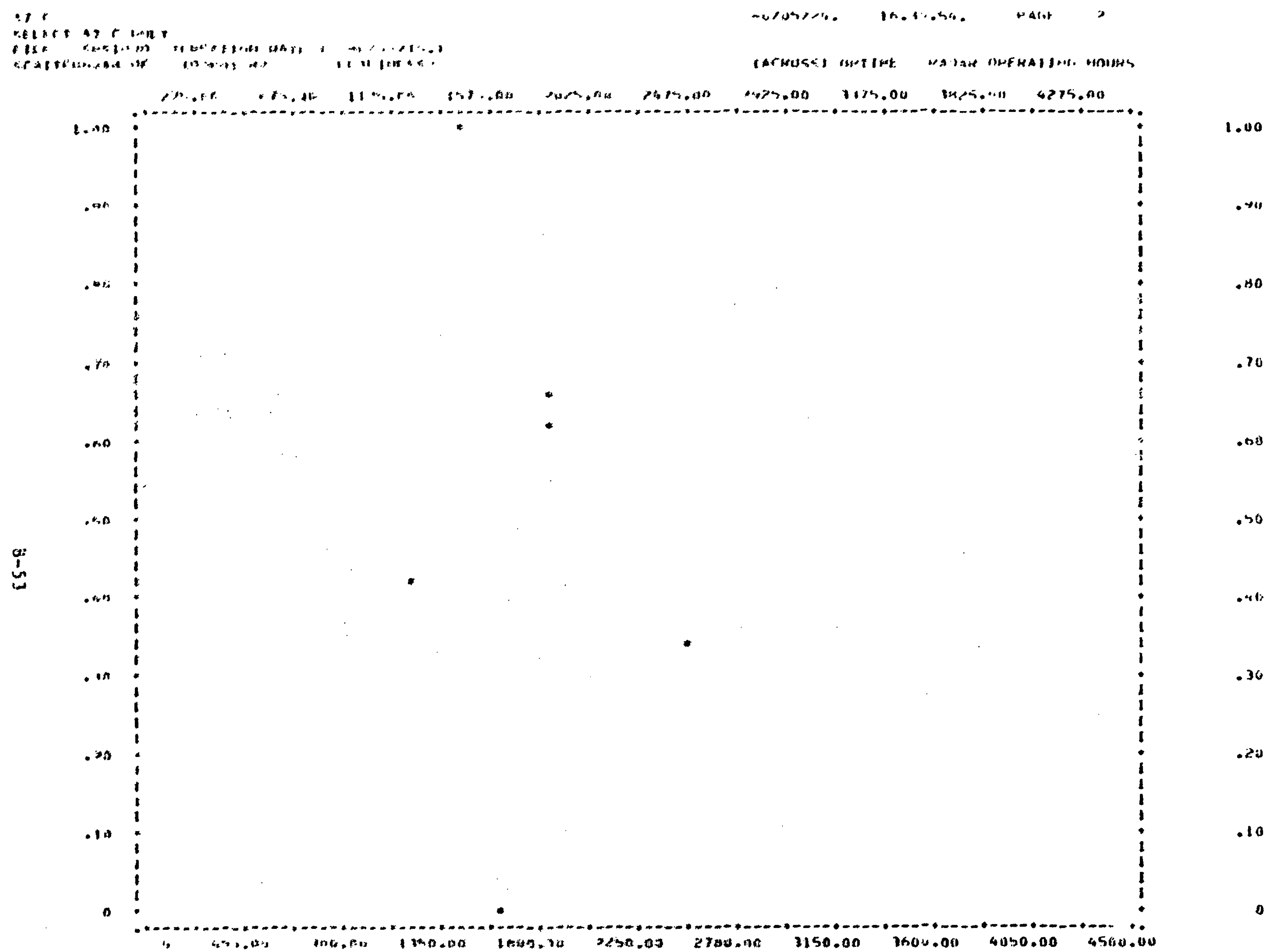
SCATTERGRAM OF (DOWN) R1 READINESS1
(ACROSS) OPTIME RADAR OPERATING HOURS



DA A
SELECT DA A ONLY
FILE SPSIPVO (CREATION DATE = 80/05/15.) 80/05/30. 11.14.54. PAGE 2

SCATTERGRAM OF (DOWN) RI READINESS1
(ACROSS) OPTIME RADAR OPERATING HOURS

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(ACROSS) UPTIME RADAR OPERATING HOURS
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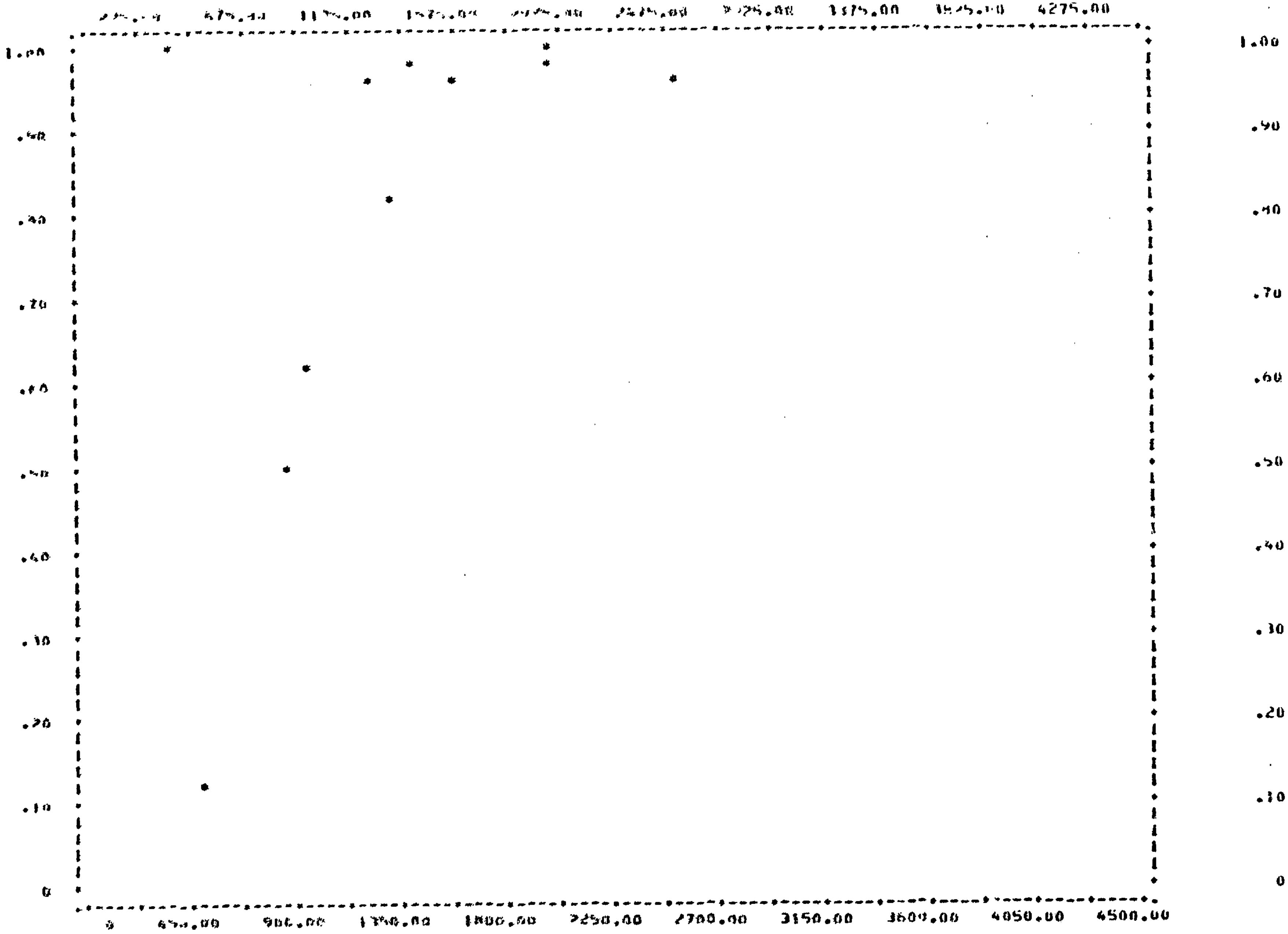
SCATTERGRAM OF

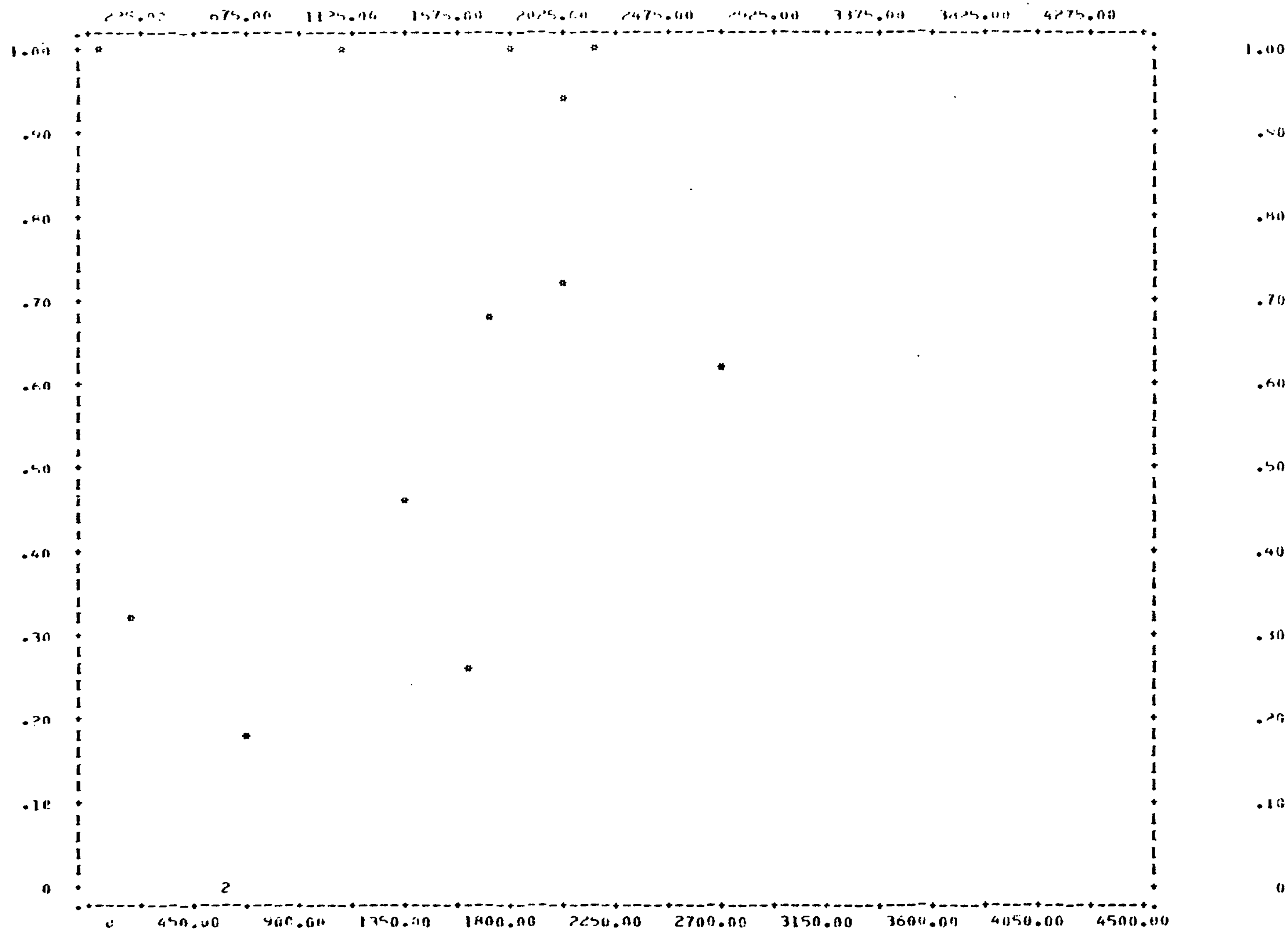
(ACROSS) UPTIME RADAR OPERATING HOURS



H7 A
SELECT H7 A ONLY
FILE SESION0 (CREATION DATE = 80/05/15.)
SCATTERGRAM OF (DOWN) R2 READINESS2

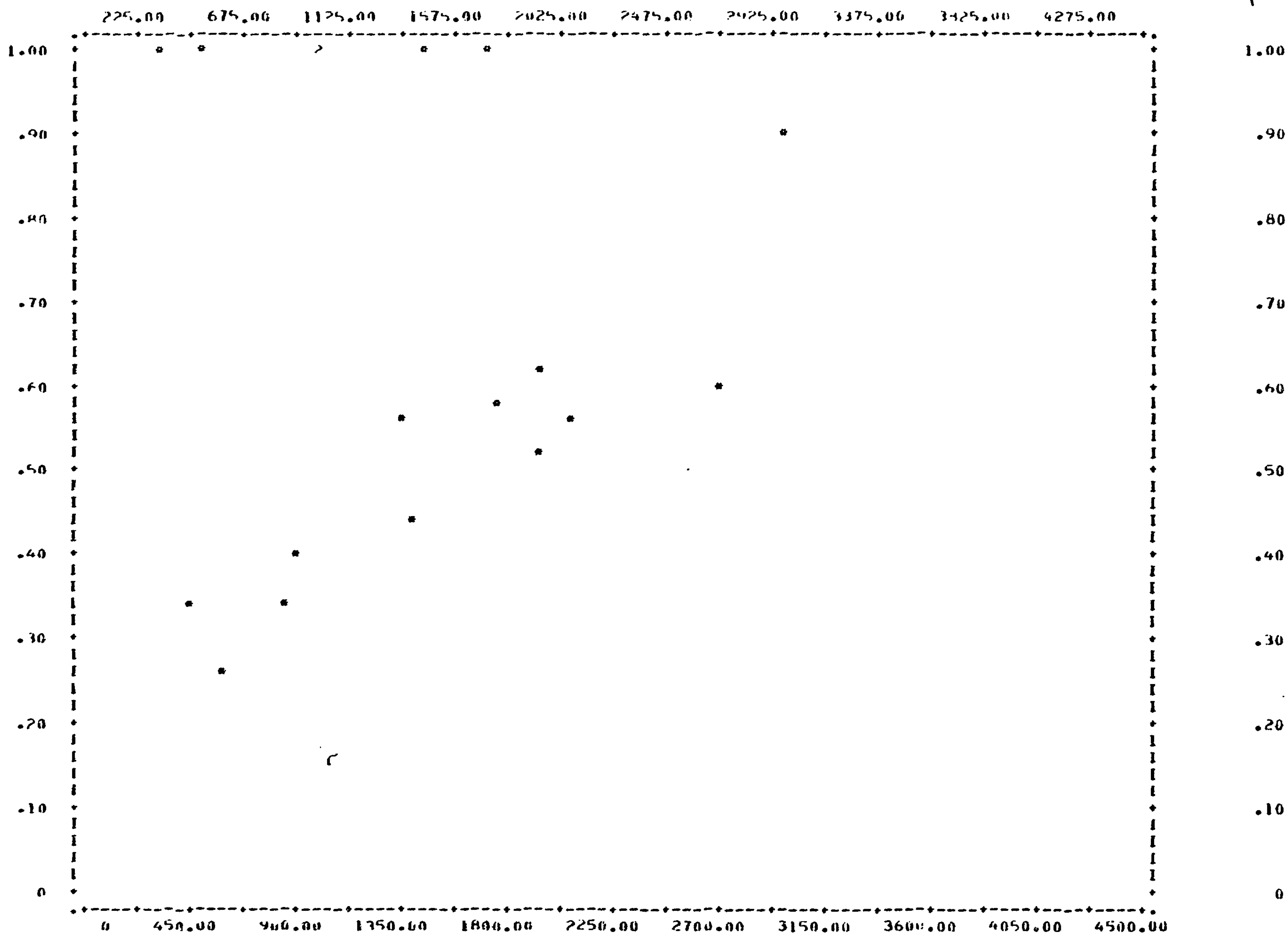
80/05/24. 16.31.33. PAGE 2

(ACROSS) OPTIME RADAR OPERATING HOURS

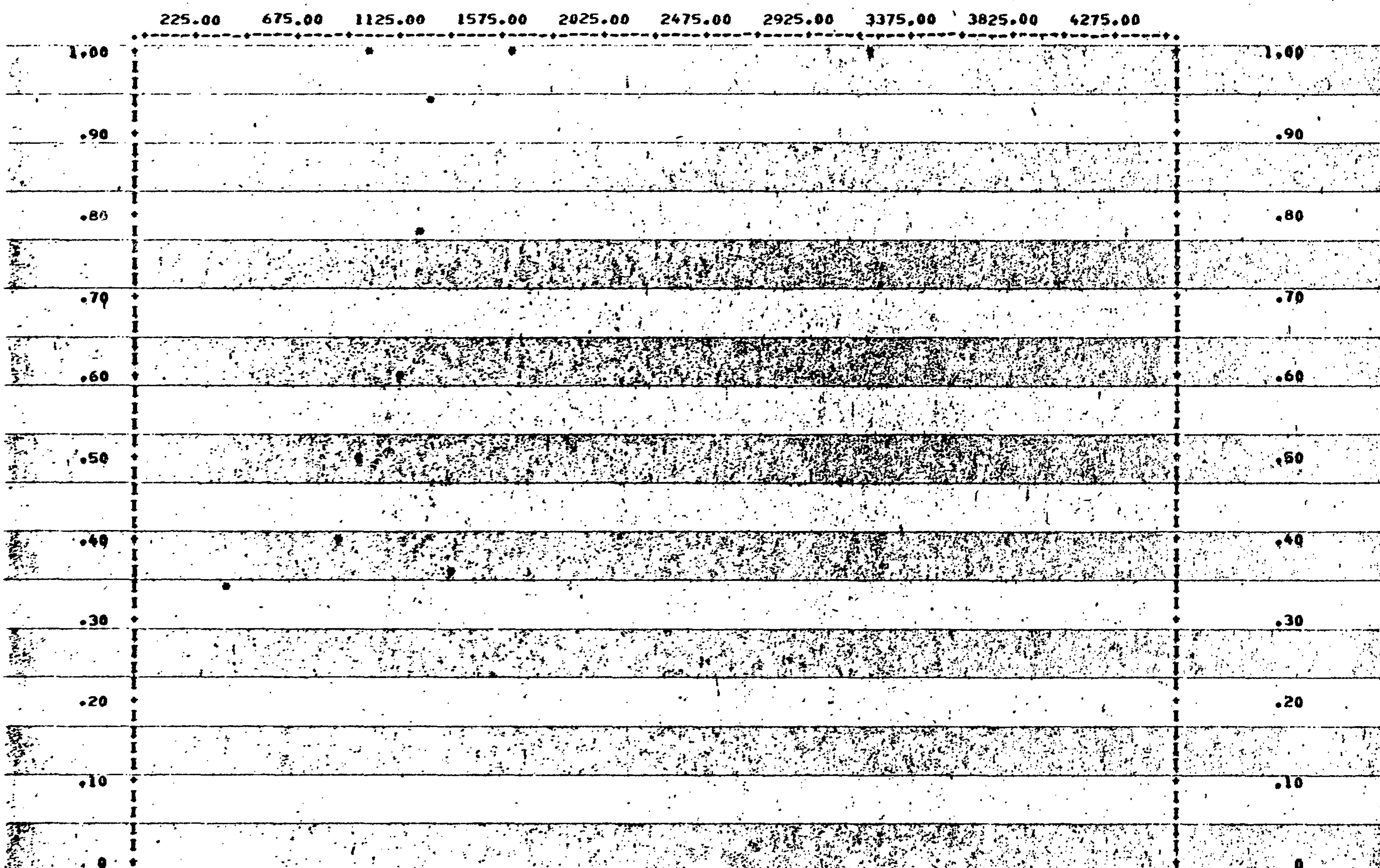


ALIA 80/05/21. 17.44.52. PAGE 2
SELECT ALIA ONLY
FILE SPS1990 (CREATION DATE = 80/05/15.)
SCATTERGRAM OF (DOWN) R1 READINESS) (ACROSS) R4 R4

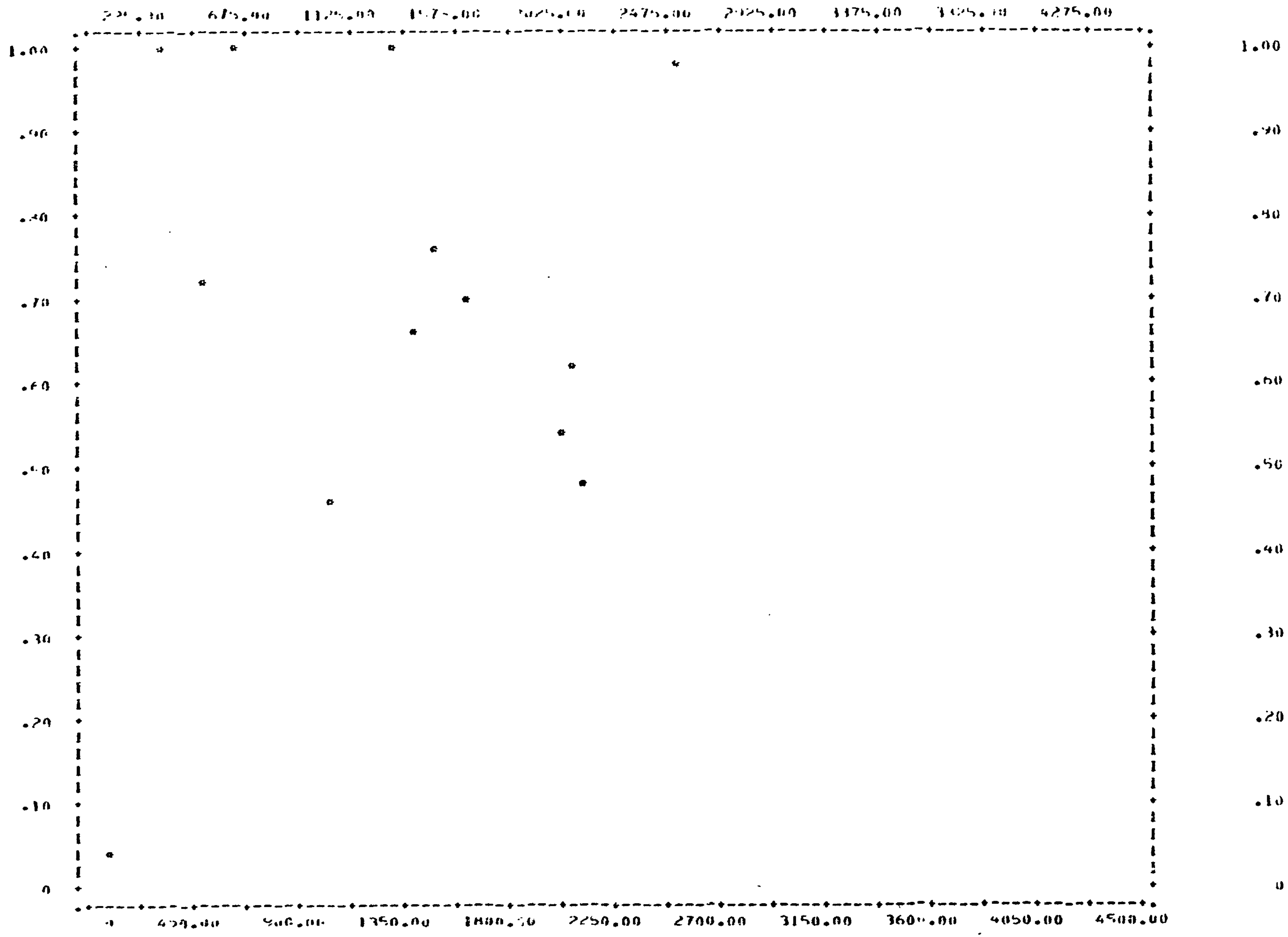
21



SCATTERGRAM OF (DOWN) R1 READINESS1
(ACROSS) R4 R4

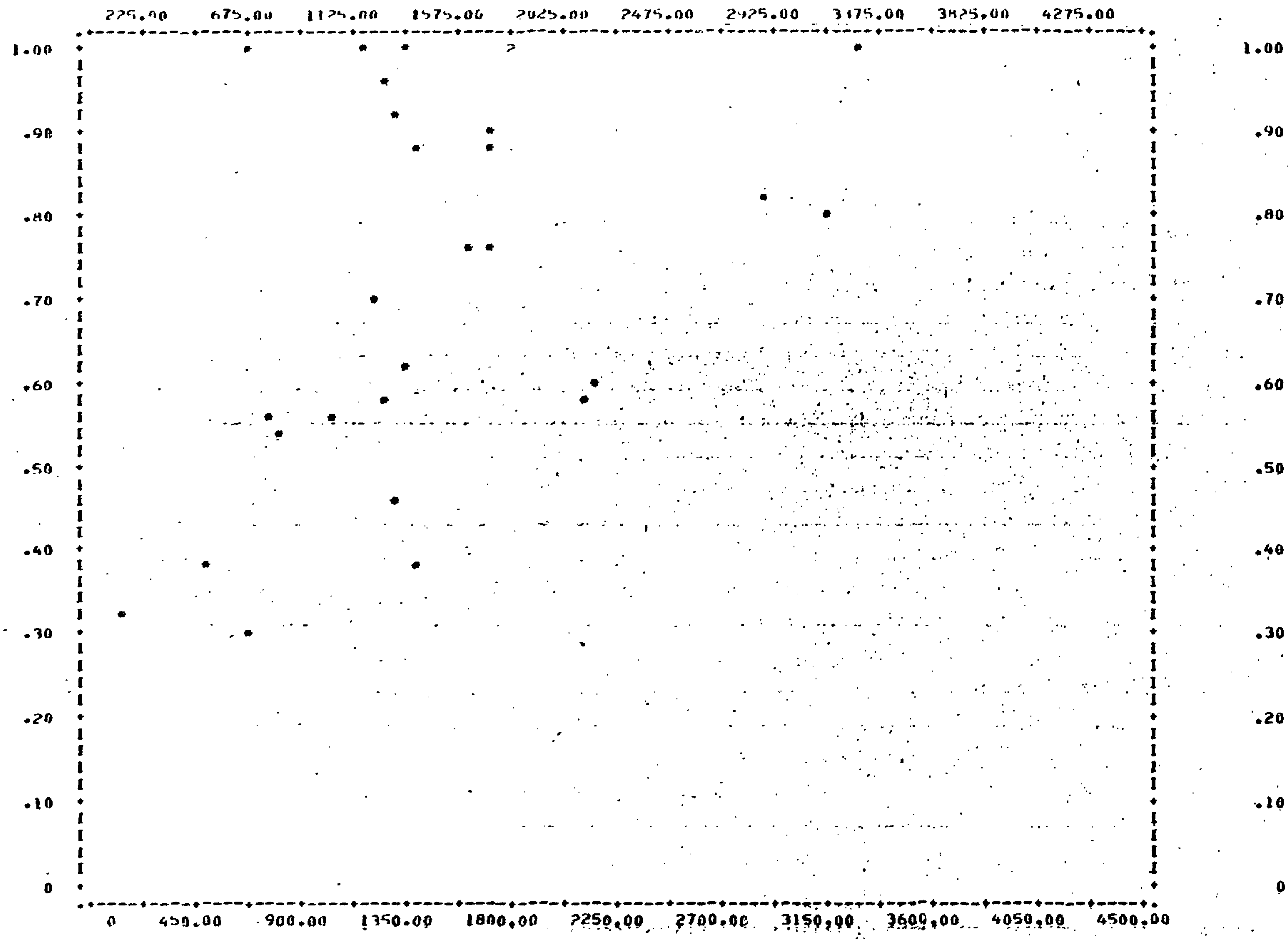


C4 V　　　　　　　　　　　　　　　　　　　　86/05/24.　　16.53.02.　　PAGE　2
SELECT C4 V ONLY
FILE　SESL... (CREATION DATE = 86/05/15.)
SCATTERGRAM OF　(DOWN) R1　　READINESS　　　　(ACROSS) R4　　R4



57 A 80/05/26. 21.1?.49. PAGE 2
SELECT 07 A ONLY
FILE SPSIP90 (CREATION DATE = 80/05/15.)

SCATTERGRAM OF (DOWN) R1 READINESS1
(ACROSS) R4 R4



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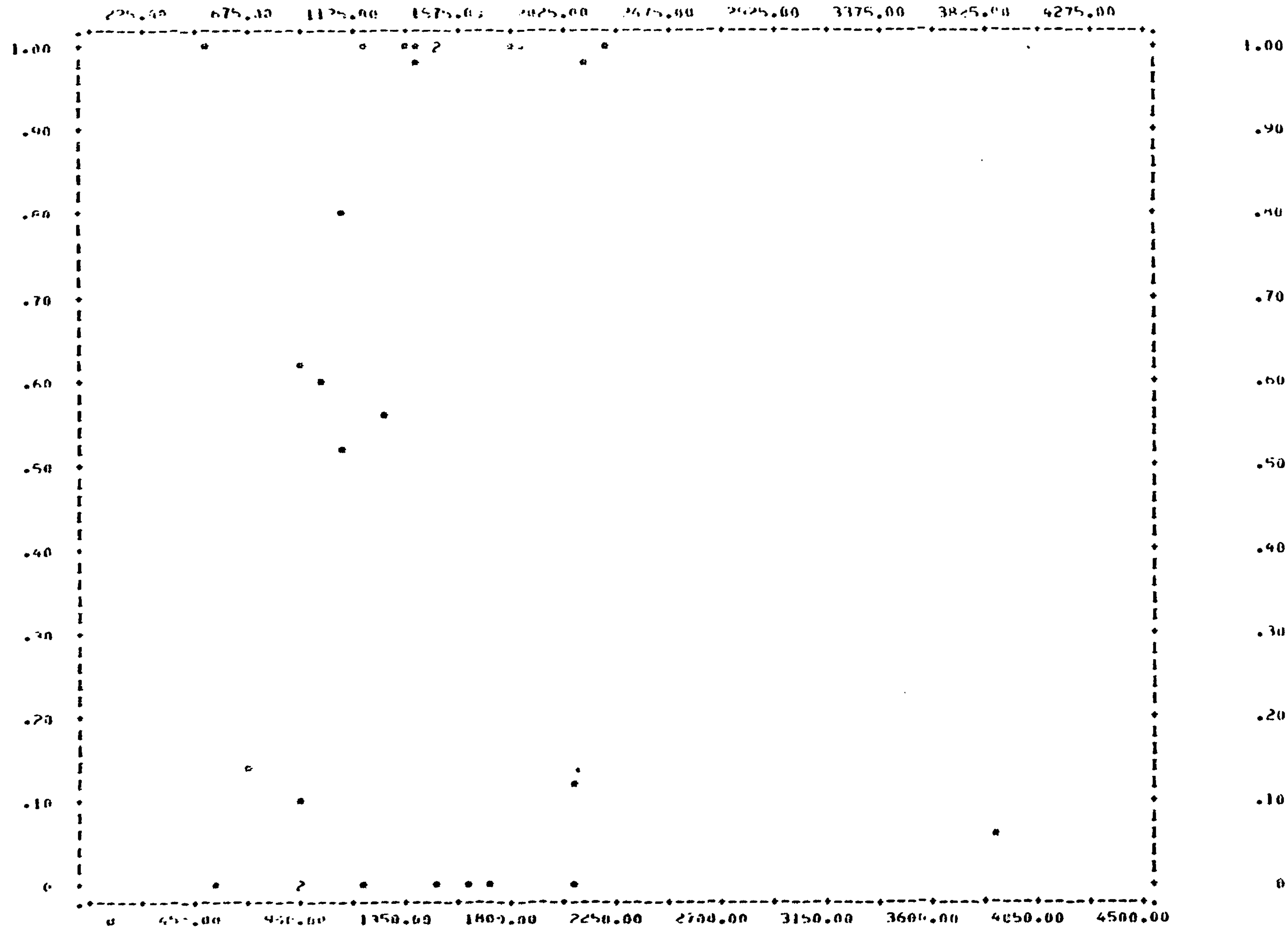
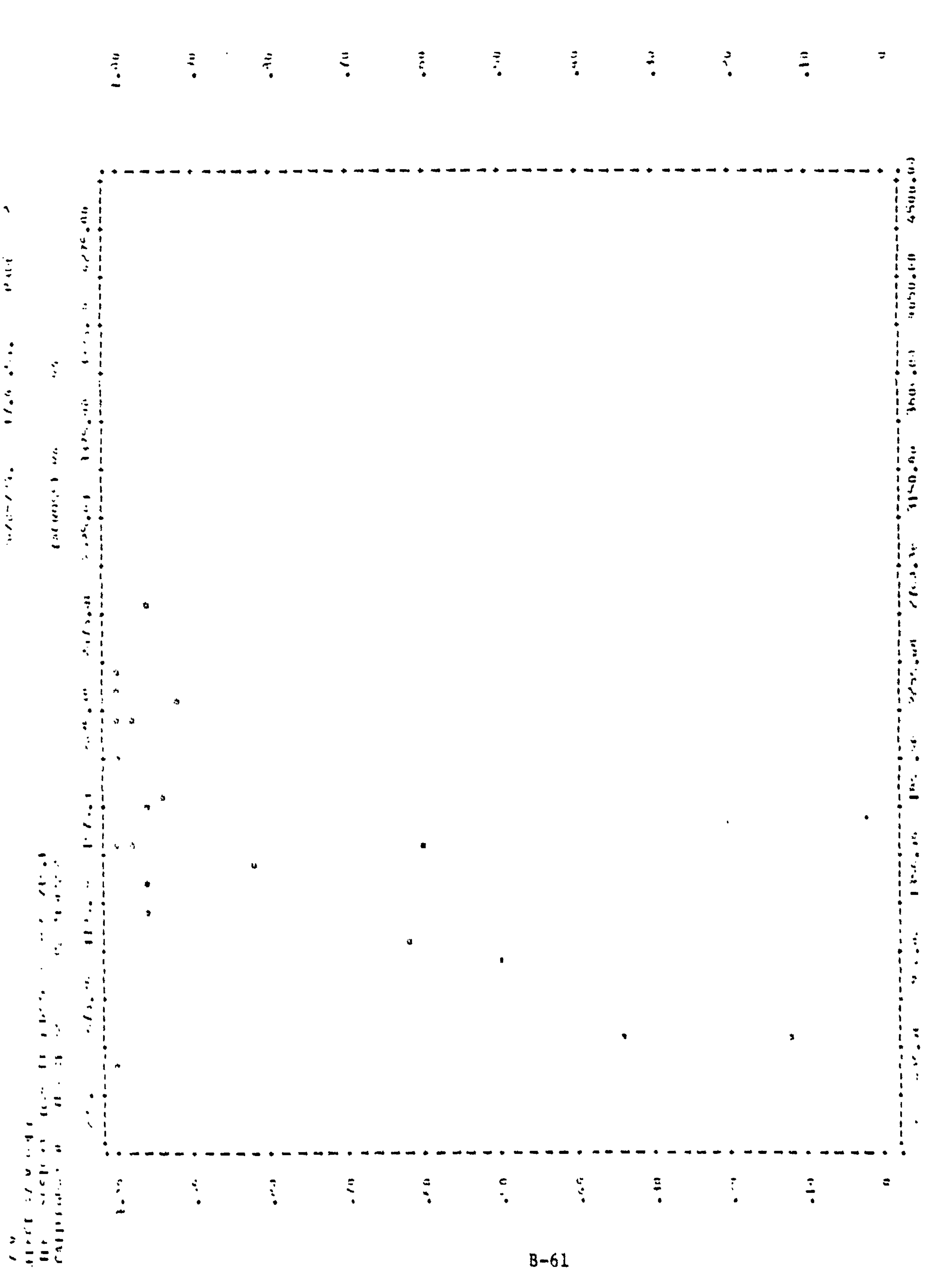
43 A                                                      07/05/24.    17.41.11.    PAGE   2
SELECT A3 & ONLY
FILE   SPS1?70   (CREATION DATE =  86/05/15.)
SCATTERGRAM OF   (DOWN) R2       READINESS2                (ACROSS) R4       R4
```





SELECT CISV ONLY
FILE SPSIG?? (CREATION DATE = ...)

SCATTERGRAM OF (DOWN) R2 ...
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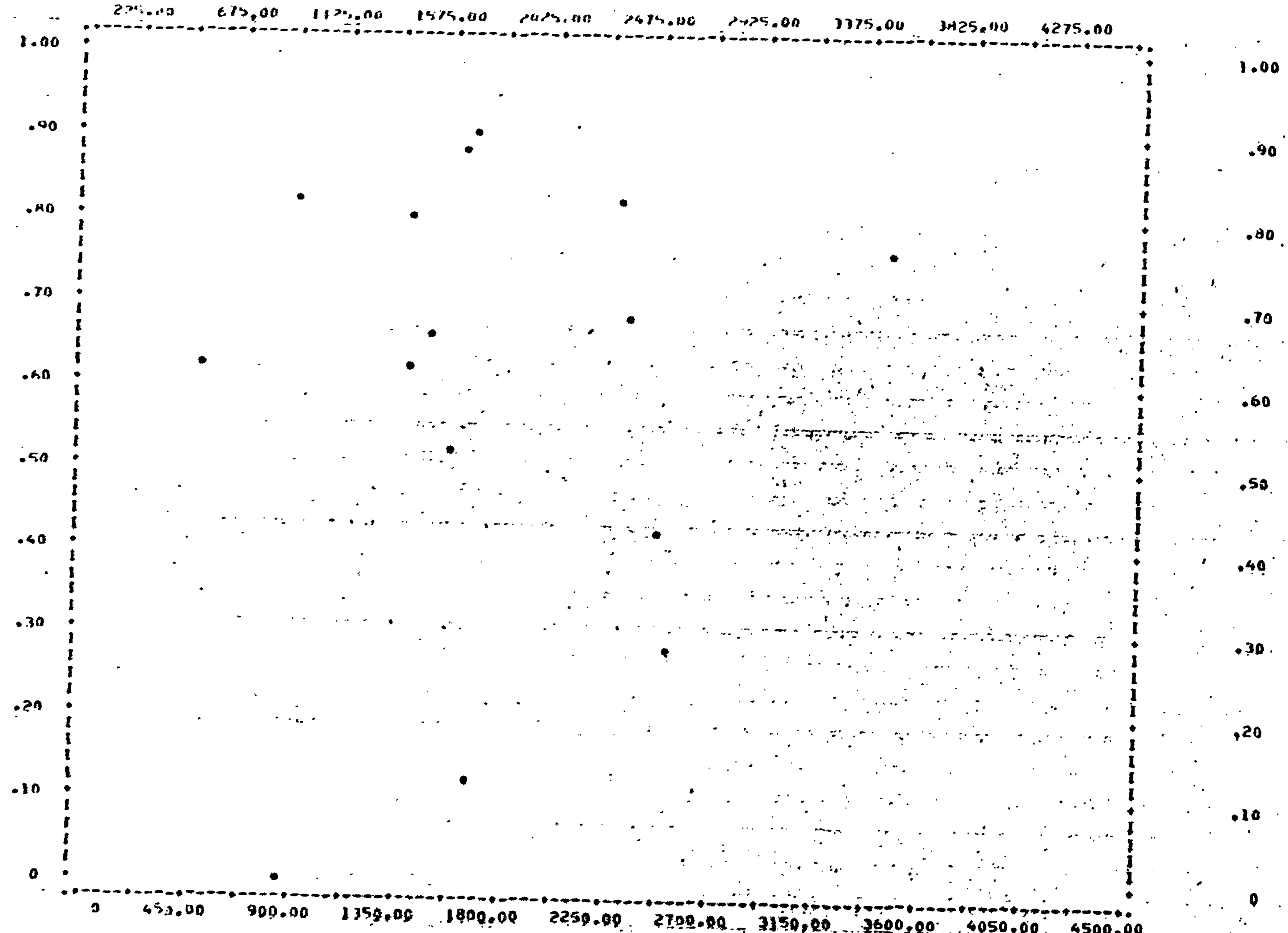

Appendix C

Data Sources and Points of Contact

DATA SOURCES AND POINTS OF CONTACT

DATA SOURCES/ POINTS OF CONTACT	DATA ELEMENTS REQUESTED
Navy Maintenance Support Office (NAMSO), Mechanicsburg, PA Mr. Geise (Autovon: 430-2043)	• Material History Reports • Electronics Equipment • Performance Reports
Ships' Parts Control Center (SPCC), Mechanicsburg, PA Ms. Gutschall (Autovon: 430-2312)	• CASREPs of AN/SPS-48 Radar Systems
NAVSEA 9315 Mr. Bartow (Autovon: 222-0553)	• Shipyard Departure Reports
NAVSECNORDIV 6643 Mr. Bartlett (Autovon: 690-9351)	• NSN Availability Reports • Unit Steaming Hours Reports • Organizational Resource Expenditures Reports
Naval Ship Weapon Systems Engineering Station (NSWSES), Port Hueneme, CA Mr. Matios (Autovon: 360-5063)	• Commanding Officers' Narrative Reports (CONARs)
ITT/GILFILLAN, Van Nuys, CA Mr. Vance (213-988-2600) Mr. Pike, SEA 62X31, (Autovon: 222-0840)	• SPS-48 Shipboard Reliability Support Program Quarterly Reports
OPNAV-643 LTJG Jelnick (Autovon: 227-0302	• FORSTAT REPORTS
COMNAVSURFLANT (N422) ETCS Norris (Autovon: 690-5257)	• East Coast MOTU Resource Expenditur

DATA SOURCES/ POINTS OF CONTACT	DATA ELEMENTS REQUESTED
COMNAVLOGPAC (N4325) LCDR Moore (Autovon: 471-9301)	• West Coast MOTU Resource Expenditur
Navy Military Personnel Command (Code 472) Mr. Stutman (Autovon: 222-5917)	• Personnel Summary of SPS-48 NEC Billets authorized/billets filled
Navy Guided Missile School, Dam Neck, VA (Code 30) CDR Cole (Autovon: 274-4489)	• SPS-48 Class "C" School graduates by rate, NEC and units to which they reported
Combat Systems Technical Schools Command, Mare Island, CA (Code 50) FTMC Gross (Autovon: 253-4330)	• SPS-48 Class "C" School graduates b rate, NEC and units to which they reported